CSC

ICT Solutions for Brilliant Minds

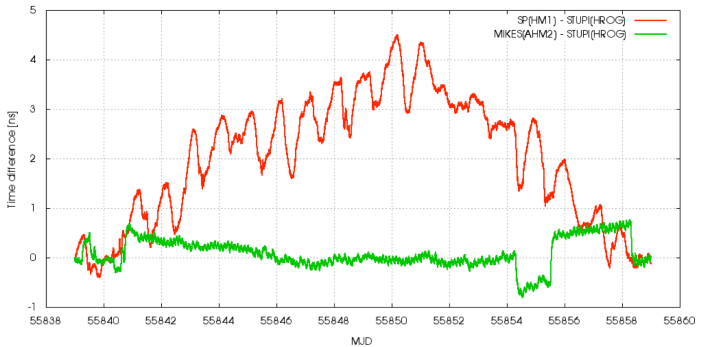
Time and Frequency services for end-users

9.3.2021, GÉANT Infoshare: European Time and Frequency Services – Principles, Challenges and Use Cases

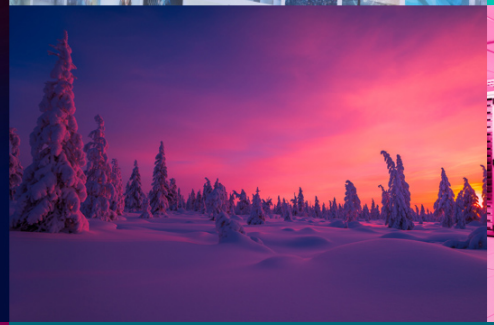
Jani Myyry, CSC/Funet

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 more than 5 years ago



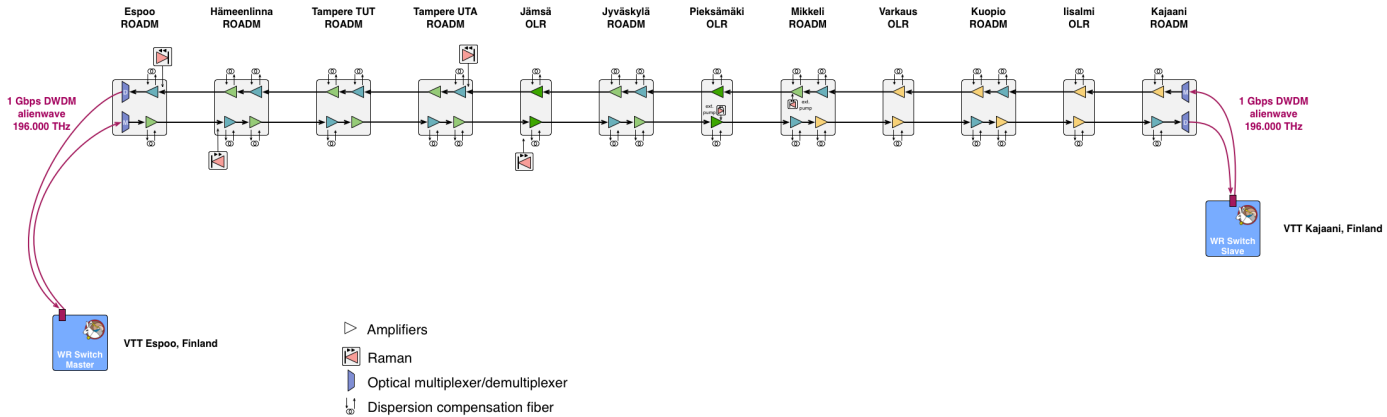
Uni-directional T&F transfer

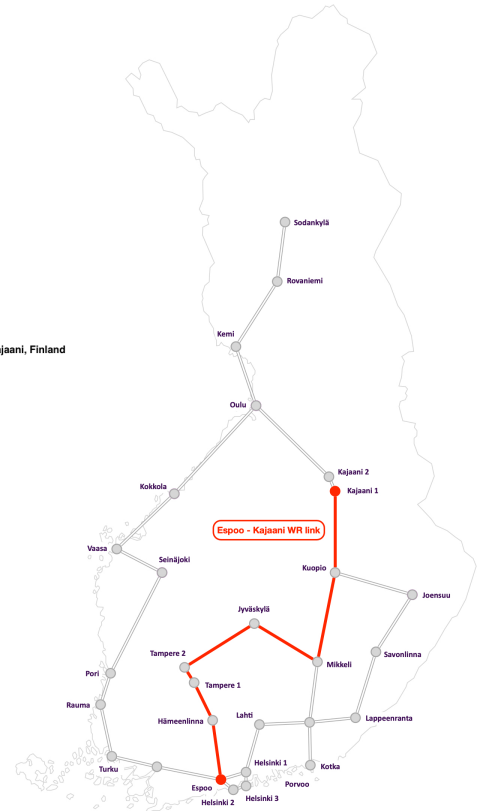


The first real T&F experience in Funet network (2013)

- VTT/Mikes approached us with a question:
  - Can we build a T&F link from Espoo to Kajaani?
- Technology would be PTP White Rabbit
  - Originally designed for max ~ 10 km links in CERN
  - But Espoo-Kajaani is ~ 800 km?
- Discussed with the DWDM vendor and asked if they would support such?
  - No, but they still provided an alienwave (for "2.5G OTU1")
- Our part was relatively easy
  1. Bought some fixed 1G DWDM SFP optics (196.0 THz)
  2. Plugged optics into White Rabbit switches and patched to the DWDM system
  3. And it just worked!
- Was the first PTP White Rabbit based long-haul T&F link in the world
  - Software required some changes as RTT was more than originally expected

Espoo – Kajaani PTP White Rabbit link (original setup)

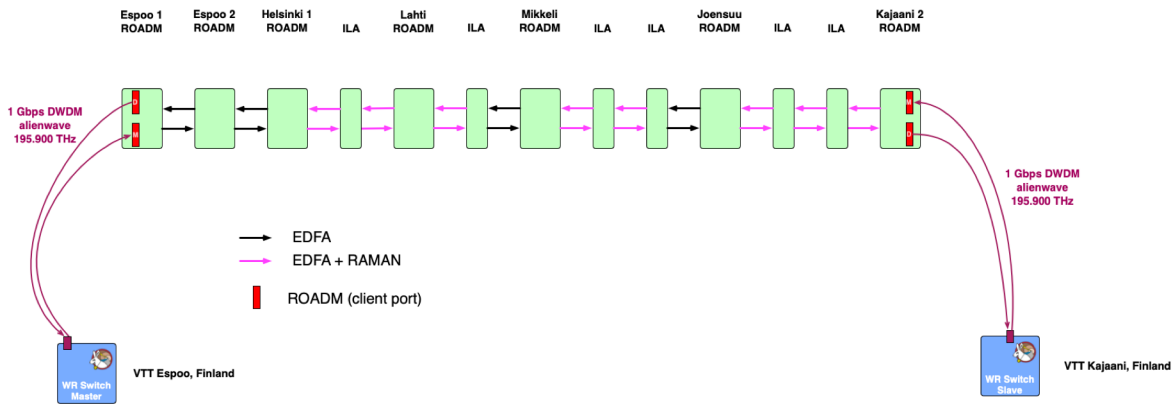


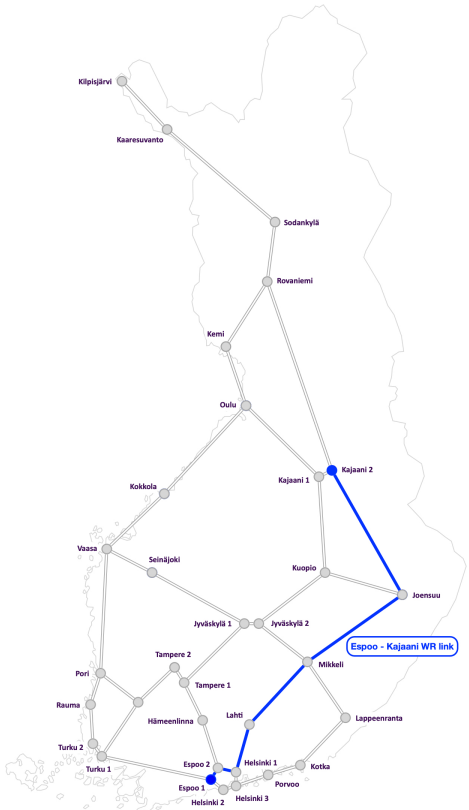


NSN/Coriant/Infinera hiT7300:

- 1G alienwave 196.00 THz
- With CD compensation
- ~ 1000 km

Espoo – Kajaani PTP White Rabbit link (current setup)



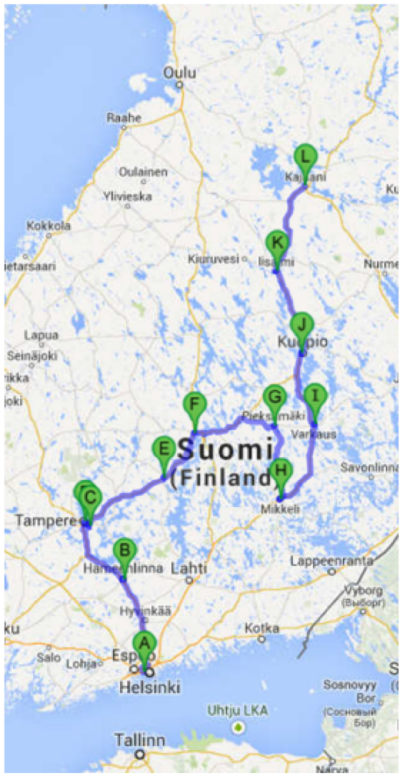


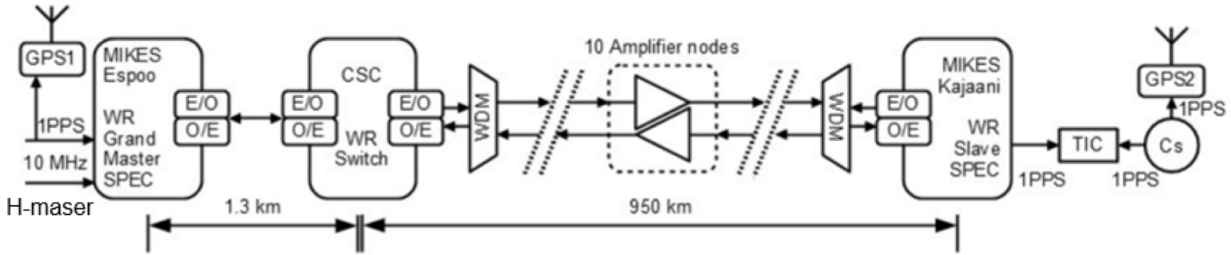
ADVA FSP3000:

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

1000 km Espoo - Kajaani link

Slide: Anders Wallin, VTT/Mikes

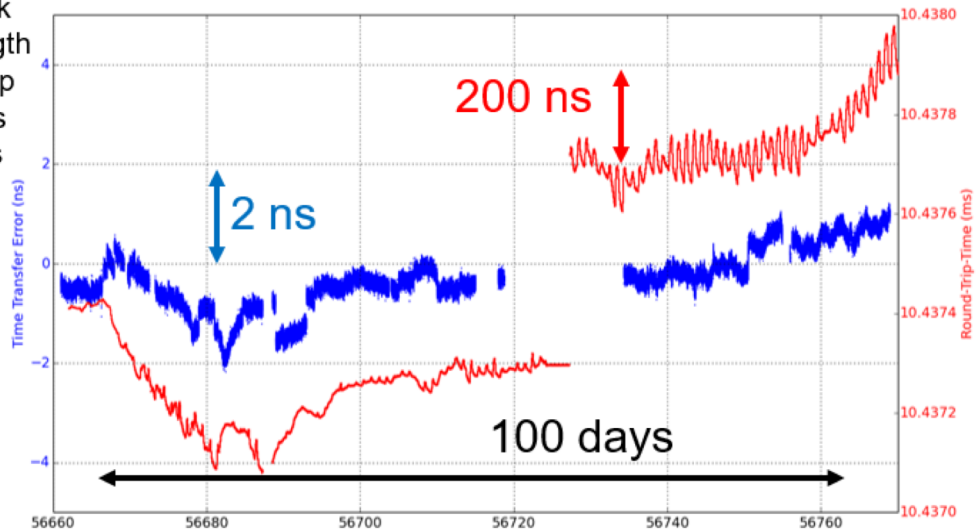




- ~~bidir~~ duplex SFPs and link
- ~~10 km~~ ~1000 km link length
- 10.4 millisecond round trip
- Uplink – downlink = ~4 us
- 12 amplifiers/multiplexers
- Longest span ~140 km

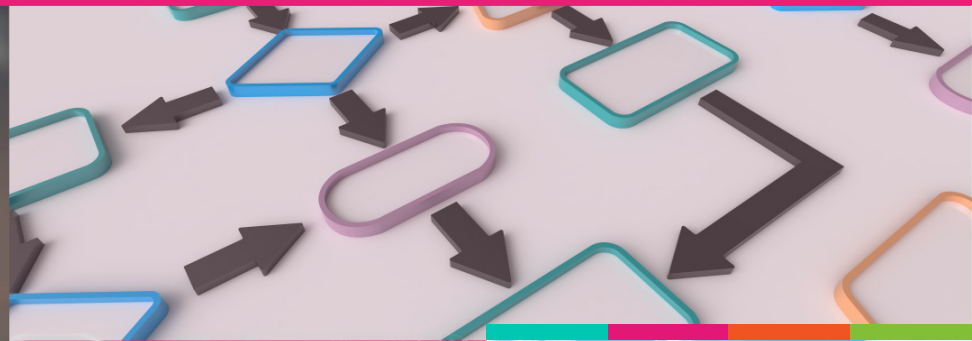
Issues:

- Network maintenance changes asymmetry
- Stability limited by Cs-clock and GPS-PPP



[Dierikx et al. http://dx.doi.org/10.1109/TUFFC.2016.2518122]

Bi-directional T&F transfer (metro)



Bi-directional T&F transfer in the metro networks

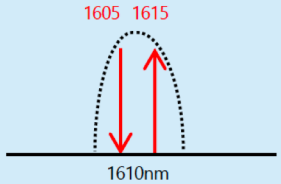
- Bidi optics and a dedicated fiber
  - 1310/1490 nm, 1310/1550 nm BX optics
  - 1605/1615 nm bidi optics (ADVA)
- CWDM filters and different Tx wavelength on both ends
  - 1470/1490 nm, …
- DWDM filters and different Tx wavelength on both ends
  - 193.90/194.00 THz, …
- Other options?

Use case: Espoo – Helsinki PTP-WR link

- Single fiber setup (in practice)
  - ADVA 1610 nm CWDM filter daisy chained with 1650 nm OTDR filter
  - ADVA 1605 and 1615 nm optics
- PTP White Rabbit switches on both ends
- Provide atomic clock reference for a Funet NTP server

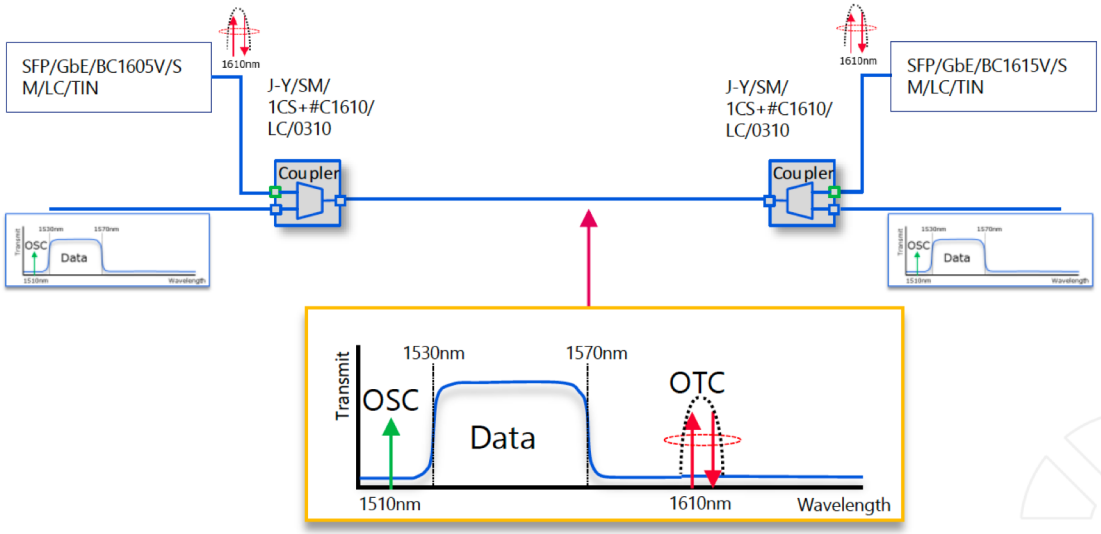
Use case: Espoo – Helsinki PTP-WR link

Single Fiber Working



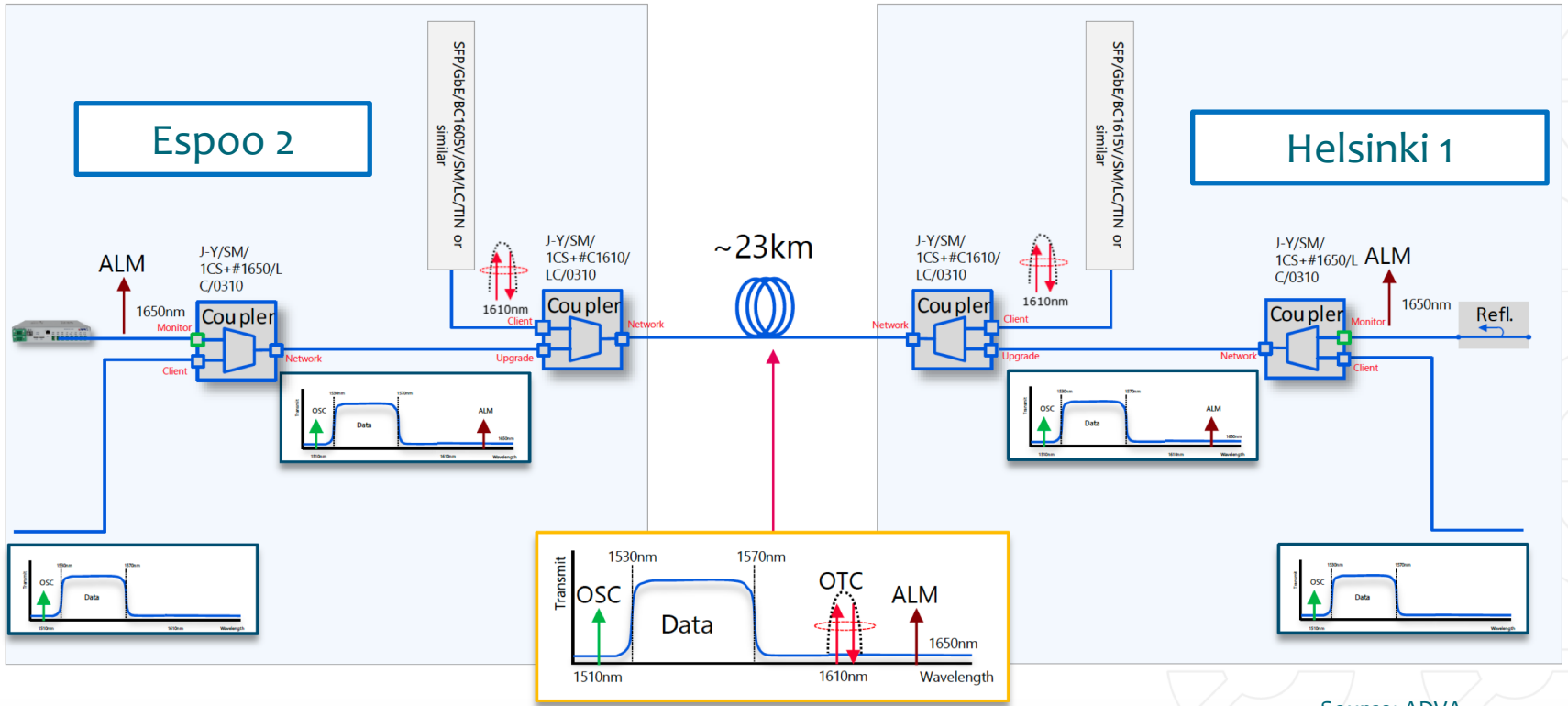
SFP/GbE/BC1605V/SM/LC/TIN
SFP/GbE/BC1615V/SM/LC/TIN

Single LC/PC Connector



Source: ADVA

Use case: Espoo – Helsinki PTP-WR link



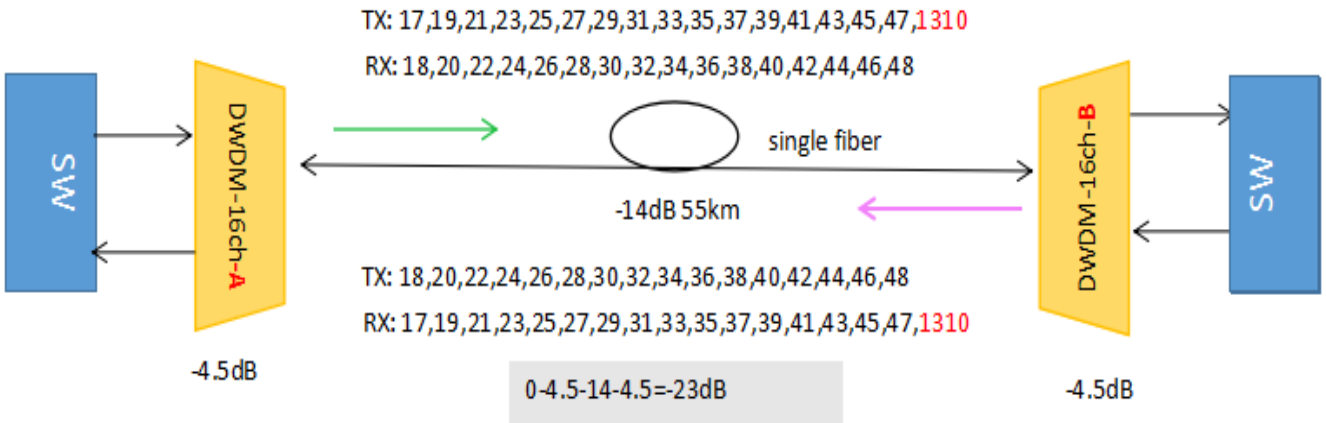
Source: ADVA

Use case: Espoo - Metsähovi T&F links

- A fiber pair (~55 km) was splitted few year ago for two purposes:
  - One fiber for data traffic
  - Another fiber for T&F signals (re-routed directly to the time lab)
    - Bidi DWDM filters + 1310 nm
- Connects VTT/Mikes and Metsähovi observatories
  - Aalto University
  - Finnish Geodetic Institute, National Land Survey
- Plans for filter renewal to support
  - 1310 +- 50 nm (ultra-stable laser, BFDA amplifiers, VTT/Mikes research project)
  - Bidi DWDM (C-band)
  - 1610 +- 6.5 nm (L-band DWDM or 1605/1615 nm bidi)
  - OTDR

1310 nm, ultra-stable laser (Thomas Fordell, VTT/Mikes):
- Will be used e.g. for testing distribution of laser pulses from a frequency comb that has been phase-locked to an ultra-stable laser (at 1348nm)
- A feedback loop will compensate for fiber phase fluctuations, and fiber losses will be compensated using bismuth-doped fibre amplifers (BDFA)

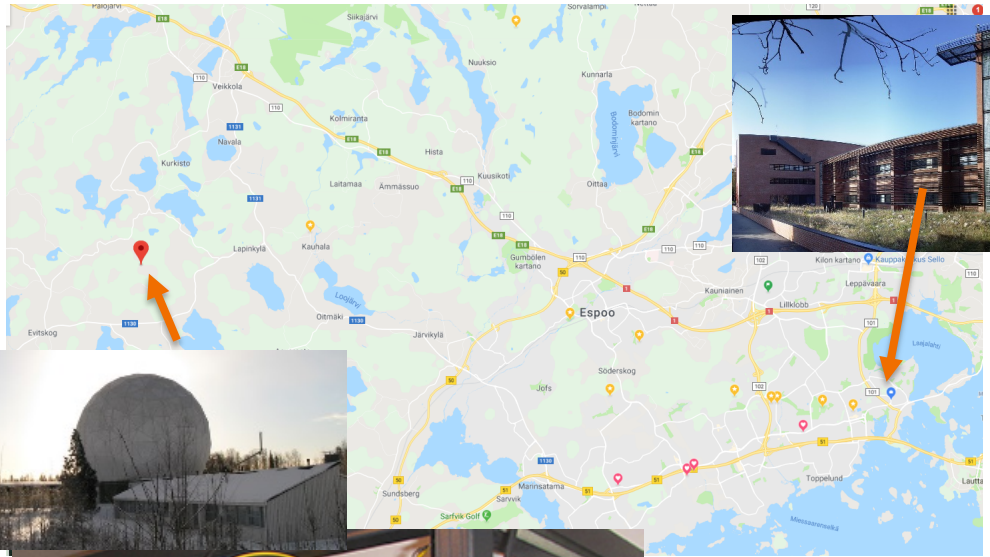
Use case: Espoo - Metsähovi T&F link (current)



Source: fs.com

Slide: Anders Wallin, VTT/Mikes

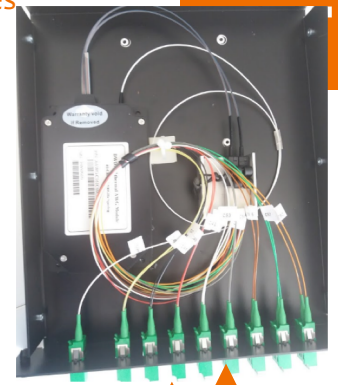
MIKES/Otaniemi – Metsähovi testbed



At remote end:

- Measurement computer
- Distribution amplifier
- Multiplexer
- Time-interval counter
- Standard WR-switch
- Low-jitter WR-switch

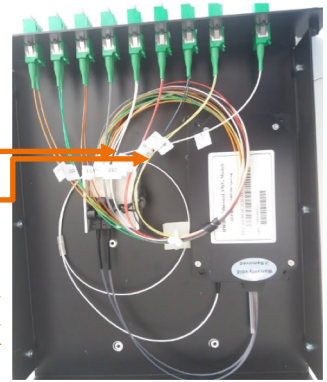
BiDir MUX



DWDM SFP 100km 1Gbit

2m fibre-pair

50km Single Dark-fibre

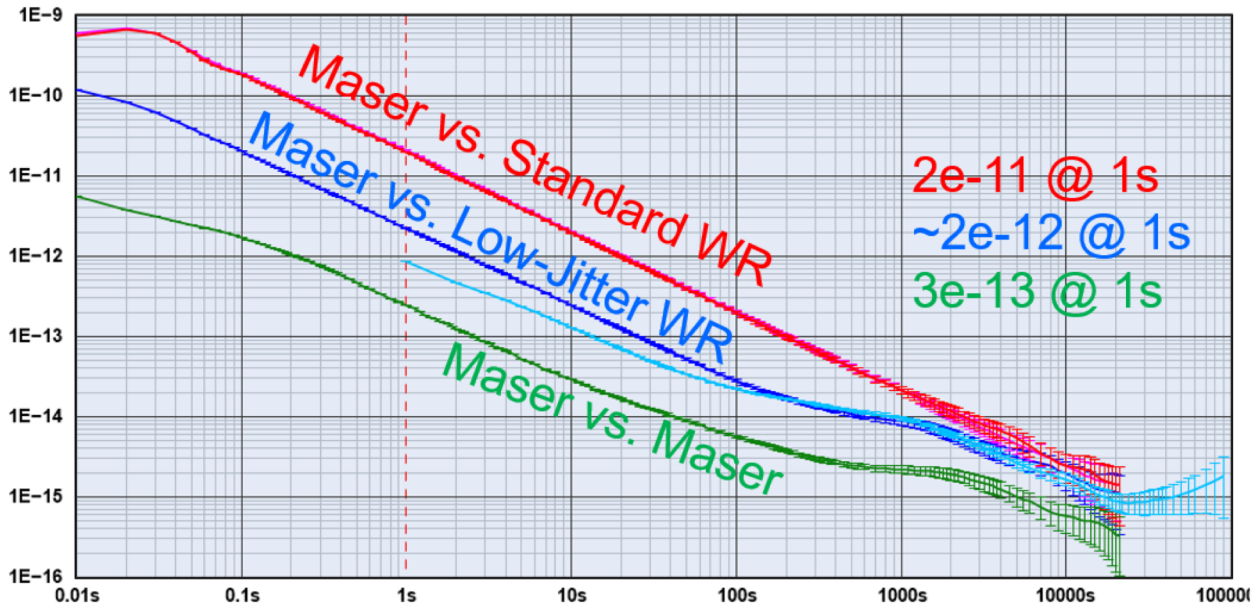


DWDM SFP 100km 1Gbit

2m fibre-pair

BiDir MUX

Results: stability
Otaniemi-Metsähovi, 50 km link



Trace	Notes	Input Freq	Sample Interval	ADEV at 1s	Duration	Acquired	
h3-lj-24h		10.000 MHz	0.010 s	2.25E−12	1d 0h 0m 0s	8640000 pts	Symm
h3-std-24h		10.000 MHz	0.010 s	2.11E−11	1d 0h 0m 0s	8640000 pts	Symm
h3-h4-24h		5.000 MHz	0.010 s	2.48E−13	1d 0h 0m 0s	8640000 pts	Symm
std-lj-24h		10.000 MHz	0.010 s	2.01E−11	1d 0h 0m 0s	8640000 pts	Symm
h3-lj-100h		10.000 MHz	1 s	8.54E−13	4d 4h 0m 0s	360000 pts	Symm

single-fibre
100 GHz (0.8 nm)
between MTX
and STX wavelengths

Slide: Anders Wallin, VTT/Mikes

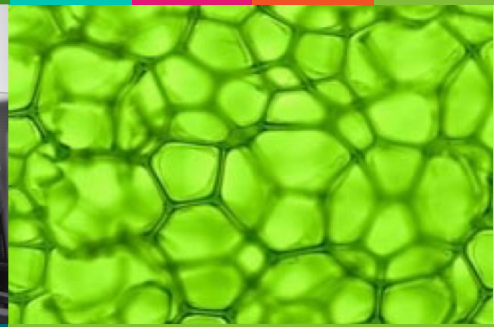
Typical asymmetry coefficients measured BiDir links

Slide: Anders Wallin, VTT/Mikes

VTT

SFP	TX / nm	RX / nm	Asymmetry
BX10	1490 nm	1310 nm	~250 PPM
Fs.com 80km	1550 nm	1490 nm	192 PPM
BiDir 1605 / 1615 nm	1605 nm	1615 nm	?? maybe 40 PPM?
Fs.com 10Gbit SFP+	1330 nm	1270 nm	14 PPM
Adjacent DWDM-channels	TX_CH	TX_CH+100 GHz (0.8 nm)	~3 PPM

Bi-directional T&F transfer (long-haul)



Bi-directional long-haul T&F challenges

- Multiple ways to implement
  - Dedicated fiber (very difficult in practice due to costs)
  - **Side-band filters and regeneration** when needed (relative easy and with acceptable costs)
  - Side-band filters and bi-directional amplifiers (if available for chosen band)
- Our experiences (will) base on side-band filters and regeneration
  - Other options are not excluded but they are more complex to implement
  - Some comments in the following slides might be vendor-specific

Bi-directional long-haul T&F challenges

- RAMAN amplifiers
  - No filters can be installed in front of the RAMAN amplifier
  - < ~ 1528 nm wont pass (in practice) RAMAN amplifiers
  - ~ 2 dB insertion loss for > C-band signals
    - Except: extensive loss in ~ 1570 nm region (ADVA)
  - ~ 2-3 dB RAMAN gain in 1600 nm region
    - 2 dB gain measured for 1650 nm OTDR signals
- 1600 nm region between C-band and OTDR (1630-1650 nm)
  - Little bit higher loss per km in G.652 fibers
  - Higher chromatic dispersion
- Extra C-band loss to be avoided if possible
  - Daisy chaining different filters not an optimum solution

Joint planning for T&F links

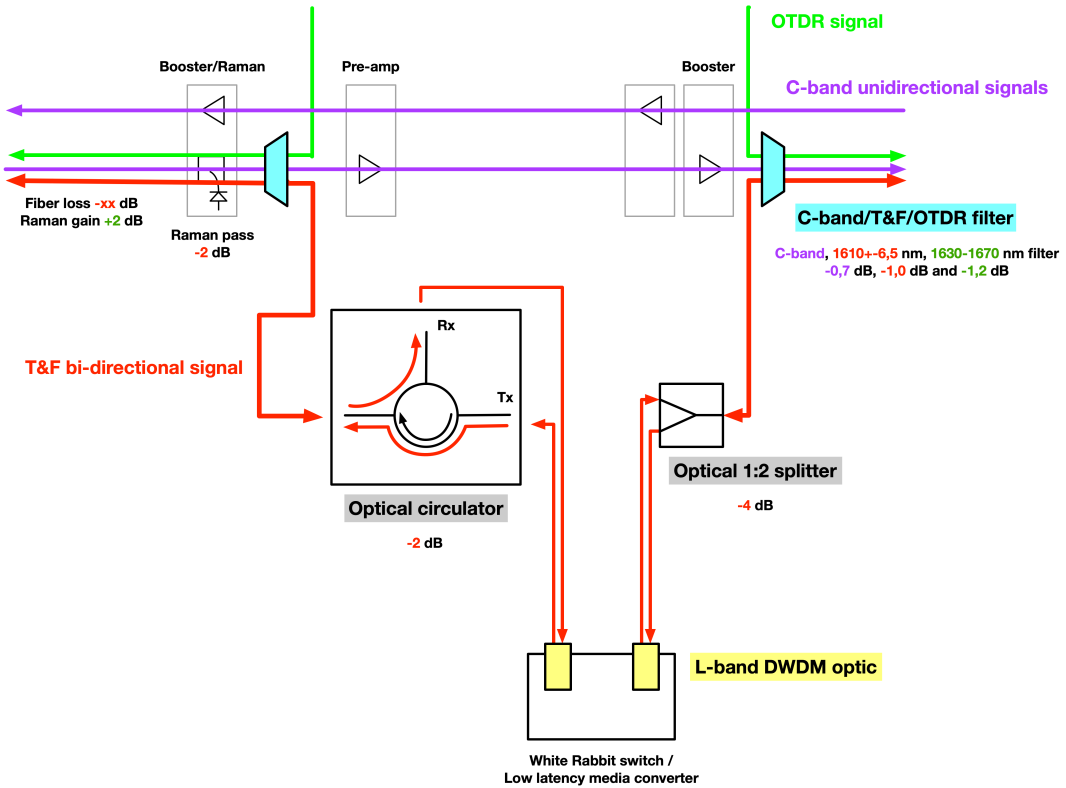
- Extensive discussions and planning late 2019
  - Funet and SUNET
  - Netnod, RISE (SE) and VTT/Mikes (FI)
  - ADVA
- 1610 +-6,5 nm chosen for T&F
  - Already tested in Finland and Sweden by using ADVA 1605/1615 nm optics and separate 1610 +-6,5 nm filters
  - L-band DWDM optics available for ~ 1610 nm with required CD tolerance
  - EDFA noise filtered out so should not be an issue (> 1570 nm)
  - Only minimal RAMAN noise expected
- White Rabbit switches and low latency/jitter media converters
  - L-band optics tested/used by Netnod/RISE
- More optimization for filtering structure…

T&F filters

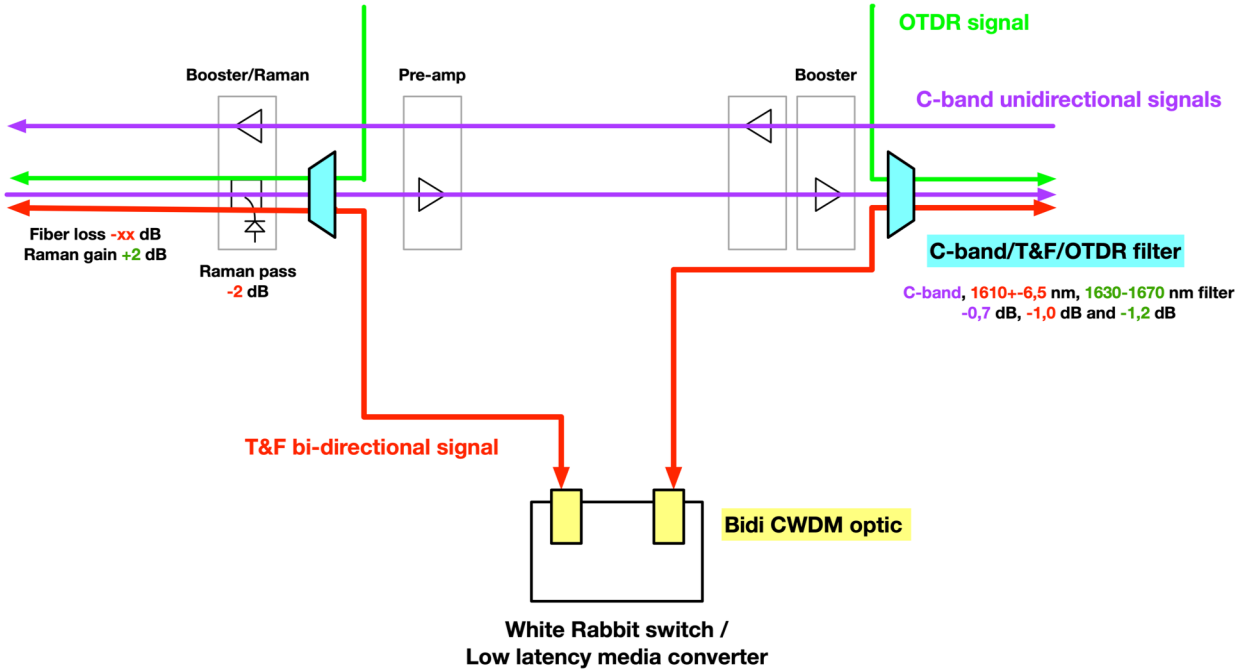
- Customized C-band (1525-1570 nm), T&F (1610 +-6,5 nm) and OTDR (1630-1670 nm) filter
  - 0,7 dB C-band loss (very important, similar with existing OTDR filter)
  - 1,0 dB T&F loss (very important on high loss links)
  - 1,2 dB OTDR loss (less important)
  - Fully bi-directional (no calibration needed)
- Customized optical circulator for high loss links (21+ dB)
  - 2 dB insertion loss
- Customized 1:2 optical splitter for low to medium loss links
  - 4 dB insertion loss
- Very low CAPEX

Photos: CSC/Funet and Netnod

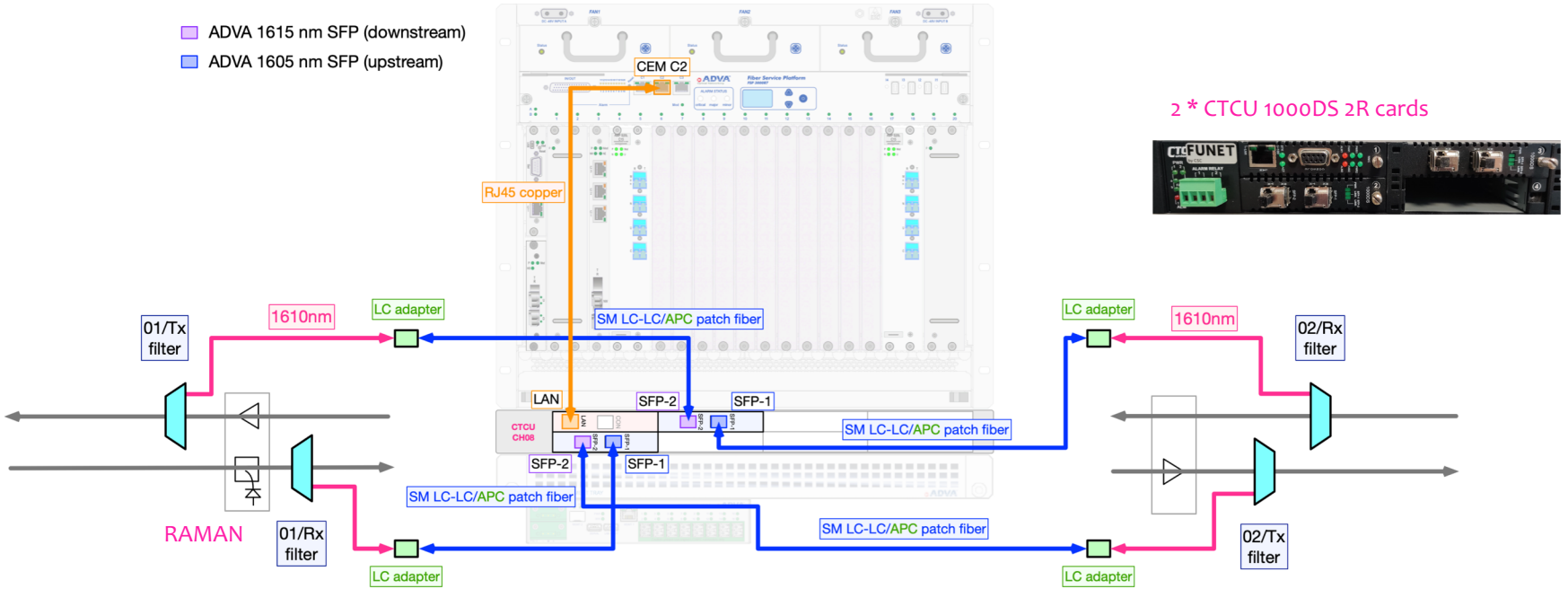
T&F filters in a node (L-band DWDM optics)



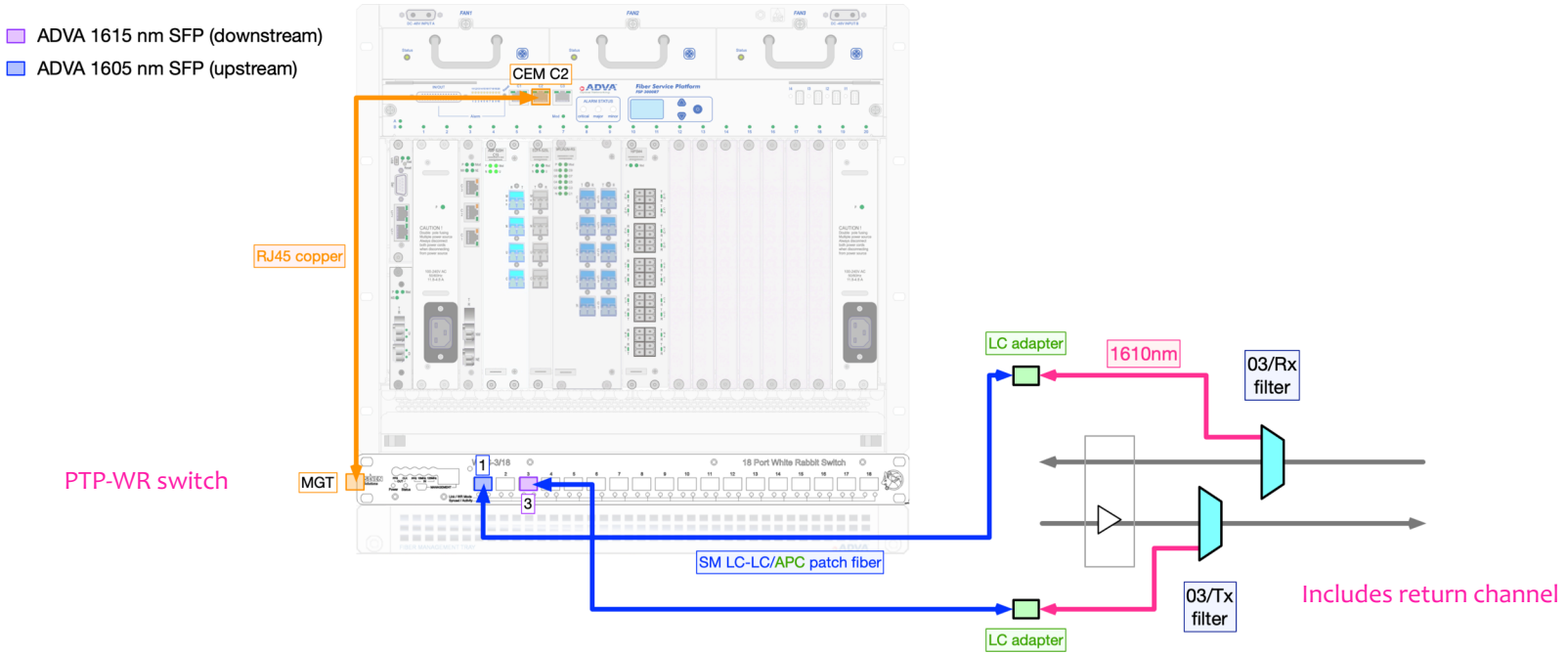
T&F filters in a node (bidi ADVA optics)



Use case: Kajaani-Oulu bidi PTP-WR link (ILA sites)



Use case: Kajaani-Oulu bidi PTP-WR link (end-sites)



End-users, requirements and future

End-users for T&F connections

- National time lab
  - Distributed clock sites
  - Services for research infrastructures and researchers
  - International links to other national time labs
- Distributed research infrastructures
- Universities and research institutes
  - Very few end-users so far (5G test stations, reference for time servers)
- Industry
  - Potentially smart grids, telecom networks (5G), etc.
  - An NREN role here?
- National critical infrastructure
  - "Avoid dependency from GNSS"
  - Sustainable funding required

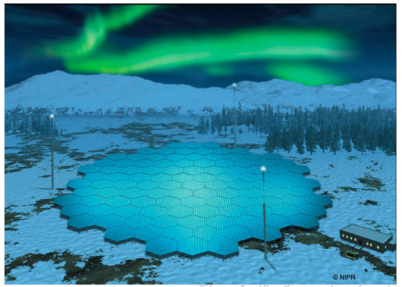
Responding to end-user requirements

- **Collaboration** with time labs and research infrastructures
  - Gather requirements and feedback
  - Participate planning together with end-users
- Prepare your network infrastructure
  - Require support from the vendors for **alienwaves and side-band access**
  - Standardize as much as possible but be flexible to re-engineer if needed
  - If reasonable, include support for T&F channels when the system or fiber links are build
  - A ROADM with dual WSS will help as OOK channels can be connected directly to ROADM client ports without filters
- Service models
  - Might be difficult as services are usually highly customized
  - Project funding might not fit easily to typical NREN service portfolio
  - Sometimes need to be creative…

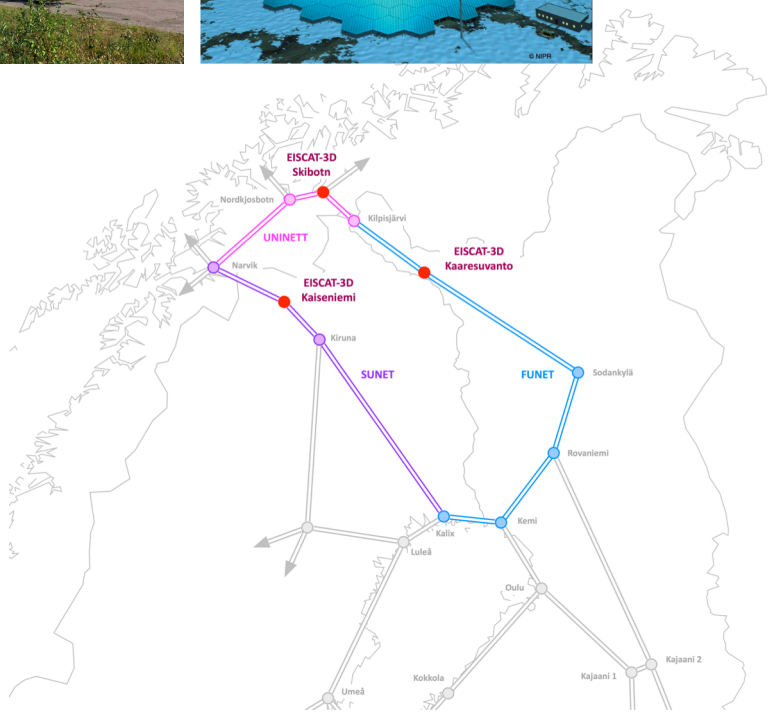
Potential new links in the future

- Finland-Sweden national time infrastructures
  - Joint planning for filters with SUNET, Netnod and FI/SE time labs
  - Both are building T&F links over 1610 nm
    - Netnod: L-band DWDM optics, WR switches
    - VTT/Mikes: ADVA 1605/1615 nm bidi optics, WR switches and 2R converters
- Finland-Estonia link?
  - Filters already installed
- More research sites in north?

EISCAT-3D

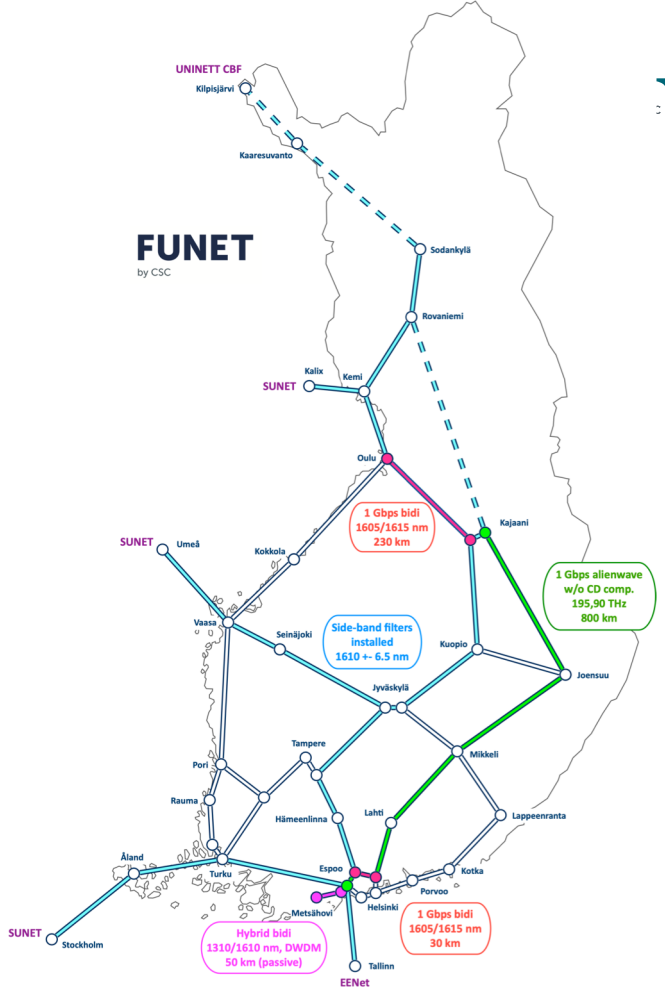


- EISCAT-3D international research project
  - Radar observations and incoherent scatter techniques to investigate Earth's atmosphere
  - Stations located in Kaaresuvanto (FI), Kaiseniemi (SE) and Skibotn (NO)
- Centralized model for computing
  - Computing clusters in Skibotn (NO)
  - Raw data from the antenna fields transported to computing site
  - ~ 4 Tbps data streams per remote site (in FI and SE) over 3 NRENs' optical networks
- Uses PTP White Rabbit for intra-site synchronization
  - Long-haul PTP White Rabbit between sites?
  - Partially prepared with side-band filters



T&F services and infrastructure in Finland

- Current services
  - Espoo-Kajaani PTP-WR unidirectional alienwave
    - VTT/Mikes time labs
  - Espoo-Helsinki PTP-WR bidi 1605/1615nm
    - Funet NTP server reference
  - Espoo-Metsähovi PTP-WR bidi DWDM
- Under construction
  - Kajaani-Oulu PTP-WR bidi 1605/1615nm
    - VTT/Mikes
- Side-band filters (1610 +- 6.5 nm) installed
  - South-north route
  - 3 * FI-SE CFBs
  - FI-EE CBF
- Future network extensions supported by default



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