QKD, Timing and Fibre Sensing in GÉANT project

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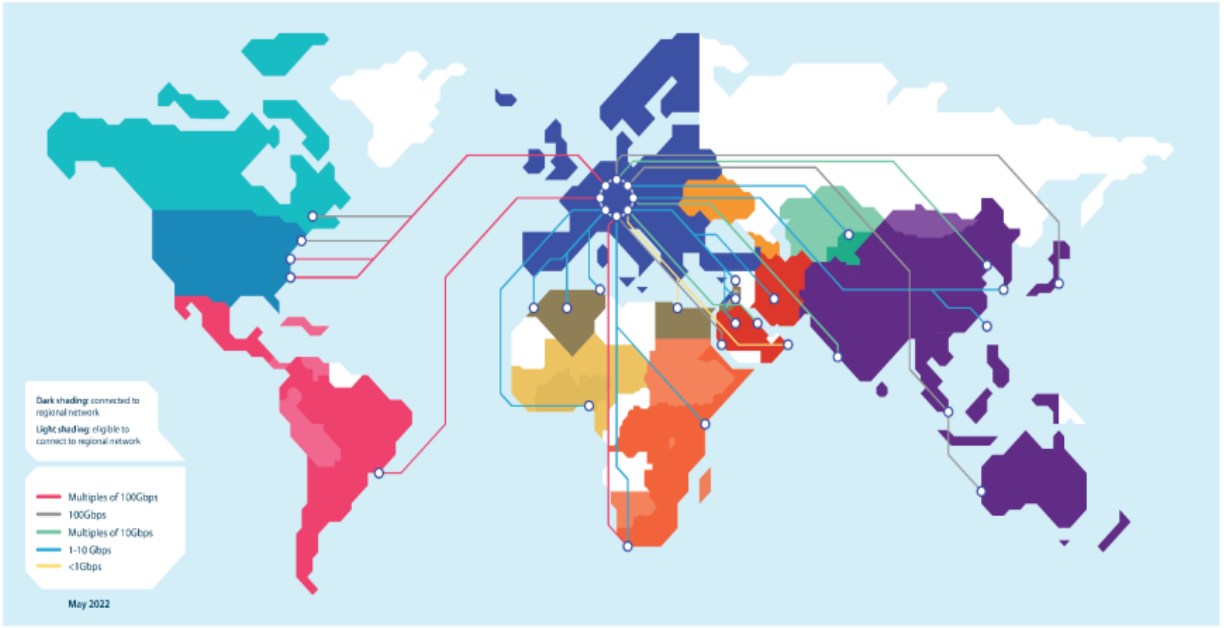
OUTLINE

- **GÉANT project and network introduction**
- Quantum Key Distribution
- Optical Time and Frequency Network
- (Submarine) Fibre Sensing

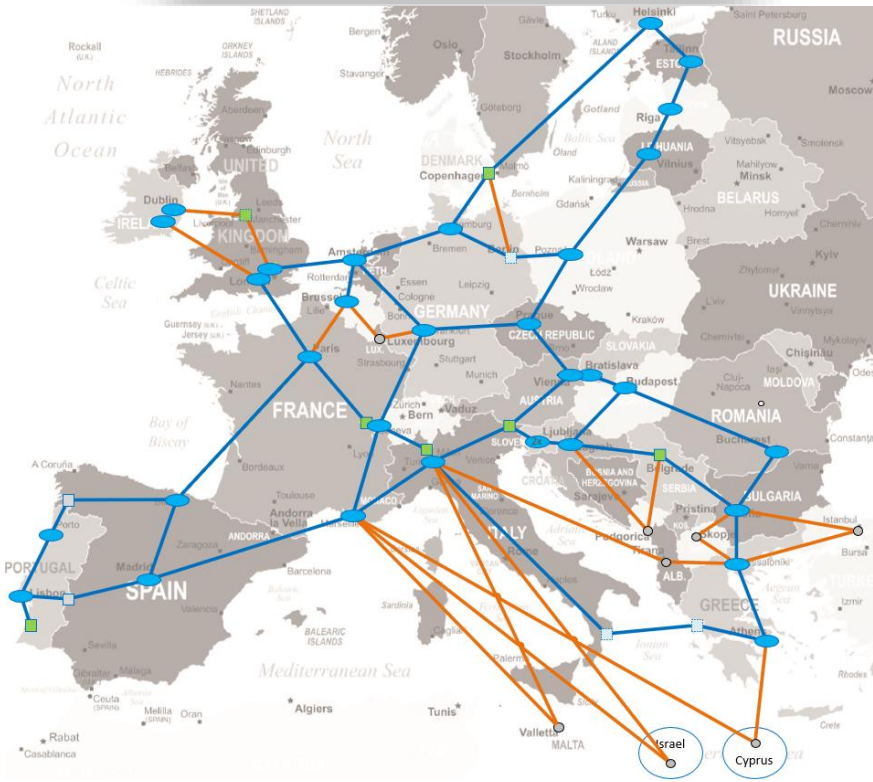
GÉANT project introduction

- GÉANT association supports and represents over 40 NRENs across Europe
- Similarity with Internet2 in US
- Together they support over 10,000 institutions and 50 million academic users
- Strong global connectivity, 35% annual traffic growth



GÉANT network upgrade

- Increase the footprint of the backbone network and improve its capacity, resilience and flexibility.
- 100 Gbps network access to a greater number of GÉANT partners and significantly diminish the digital divide.
- From 14 to 32 countries connected by Fibre/Spectrum
- From 8,000 to 19,000 Km Fibre
- 12,000 Km Spectrum, 7000 Km from NRENs
- Based on 15+ years IRU
- Maximum achievable capacity per link between 6 and 24+ Tbps



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NRENs participation in the NatQCIs

- HellasQCI – Greece | GRNET
- PIONIERQ – Poland | PSNC
- CroQCI – Croatia | CARNET
- IrelandQCI – Ireland | HEANET
- RoNaQCI – Romania | RoEduNet
- CZQCI – Czechia | CESNET
- QCINed – The Netherlands | SURF
- CYQCI – Cyprus | CYNET

- About 24 national QCI deploy projects in EU
- Large number of NRENs **lead** or **participate** to the NatQCIs and there are NRENs that participate **indirectly** to the NatQCIs
- **GEANT** through the **Quantum Strategy Group** and the **GN5-1 Quantum subtask** facilitates the **information sharing** between the NRENs
- **Exchange of expertise** is crucial to create a secure and operational EuroQCI → same challenges – most of the NRENs started from scratch

Info share link

Adopted from Ilias Papastamatiou and *Piotr Rydlichowski talk at TNC23*

Quantum: NREN support

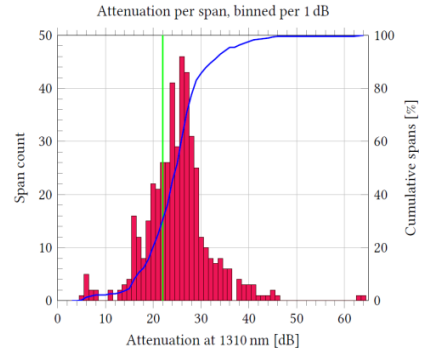
- Support platform for NRENs
  - for hardware discussions (e.g. upcoming infoshare “QKD and Quantum Solutions”: https://connect.geant.org/2023/05/31/infoshare-qkd-and-quantum-solutions-21-06-2023-1300cest)
  - e.g. with updates on latest standards (https://wiki.geant.org/display/NETDEV/Quantum+Standardisation)
  - to investigate possible NREN collaboration on
    - interoperability tests
    - hardware procurements
    - cross-border collaboration on National QCI projects

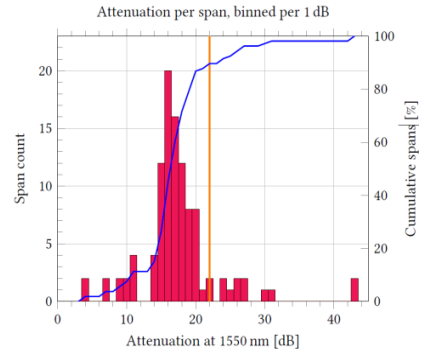
- Example of cross borders
- Real use case - urban fiber pair – 65 km, 16 dB@1550 nm
- With parallel precise time and frequency transfer

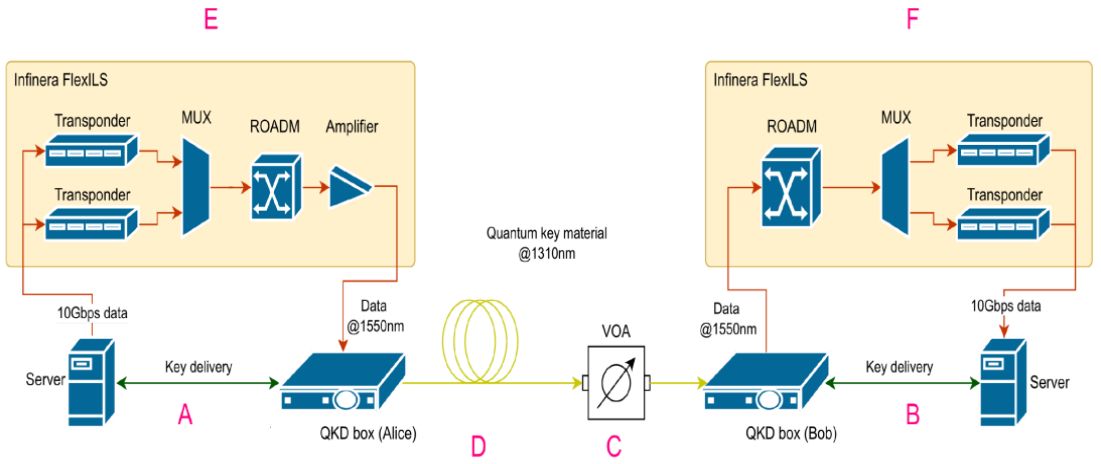
Gap analysis of future QKD service(s) in GÉANT

- Gap analysis of future Quantum / QKD service(s) for NRENs and GÉANT
- 1310 nm commercial system tested with parallel data and noise
- https://www.cesnet.cz/wp-content/uploads/2023/04/Guy-Roberts-GEANT-update-@-CEF11.pdf

- GÉANT network:
  - ~30% @1310nm
  - ~90% @1550nm







Credit: Klink K. v. et al. ***Multiplexing Quantum Key Material with Data Waves, GÉANT Infoshare – QKD deployments***

OUTLINE

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- **Optical Time and Frequency Network**
- (Submarine) Fibre Sensing

Precise timing and reference users

Fundamental Physics

https://cdn.sci.esa.int/documents/33940/35451/1567216846854-RedShift_screen.jpg

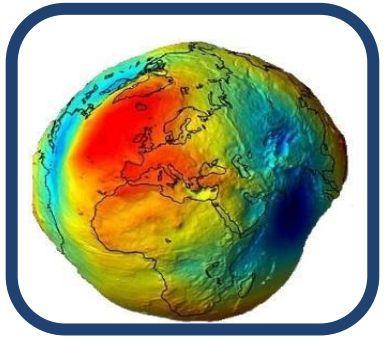
Quantum Technology

https://qusco-itn.eu/wp-content/uploads/2019/07/share_image.jpg

Optical Clocks & SI

https://www.ptb.de/cms/en/ptb/fachabteilungen/abt4/fb-43/ag-432.html

Geodesy



https://www.weltderphysik.de/typo3temp/assets/_processed_/2/b/csm_2005_lhc-tunnel_CERN_09_70a51515c6.jpg

Astronomy

https://www.nasa.gov/sites/default/files/images/419813main_Europe_SN2007gr.jpg

Navigation, GNSS

https://phys.org/news/2019-07-europe-gps-rival-galileo-outage.html

XG Telecomm.

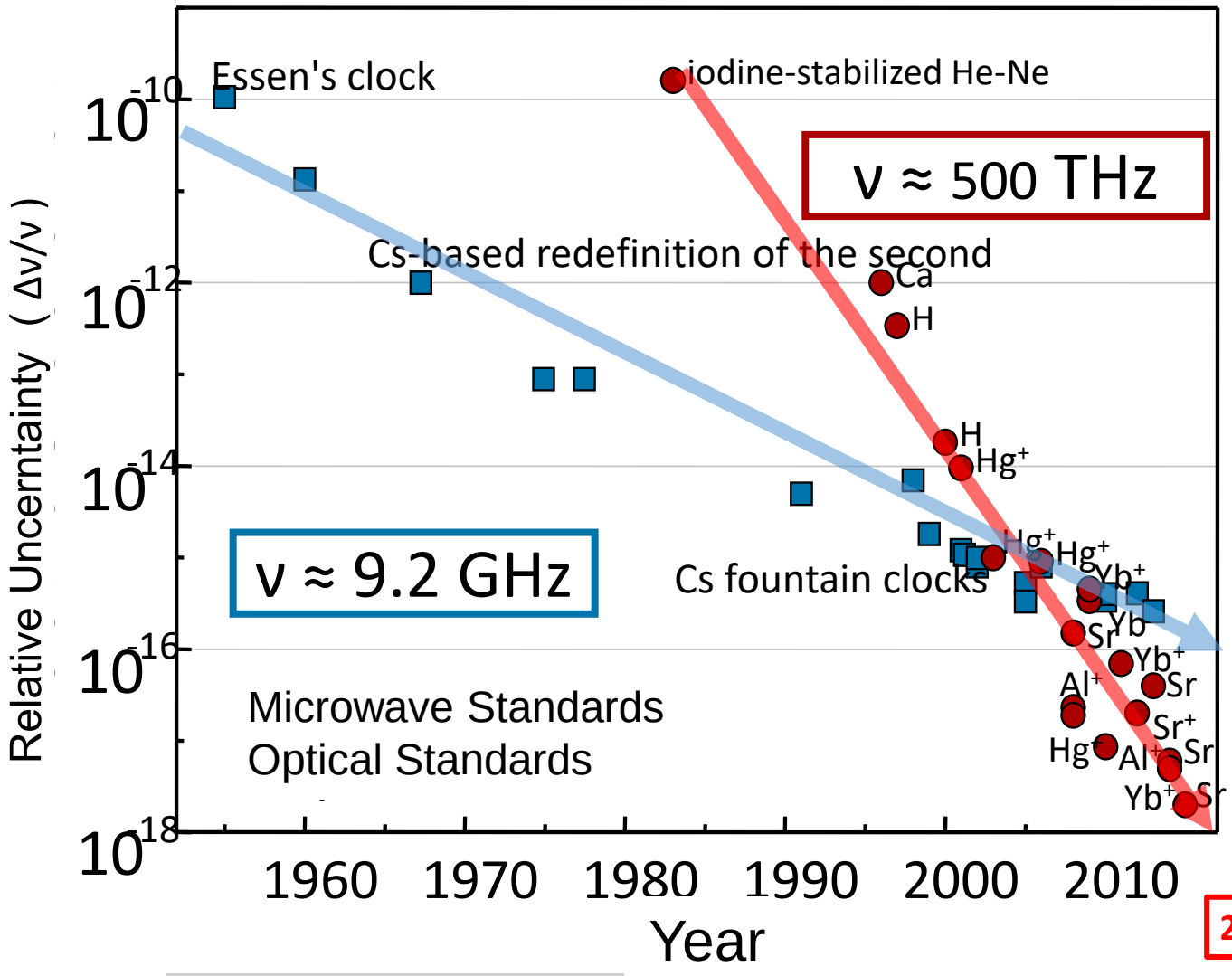
https://static.dw.com/image/49166446_303.jpg

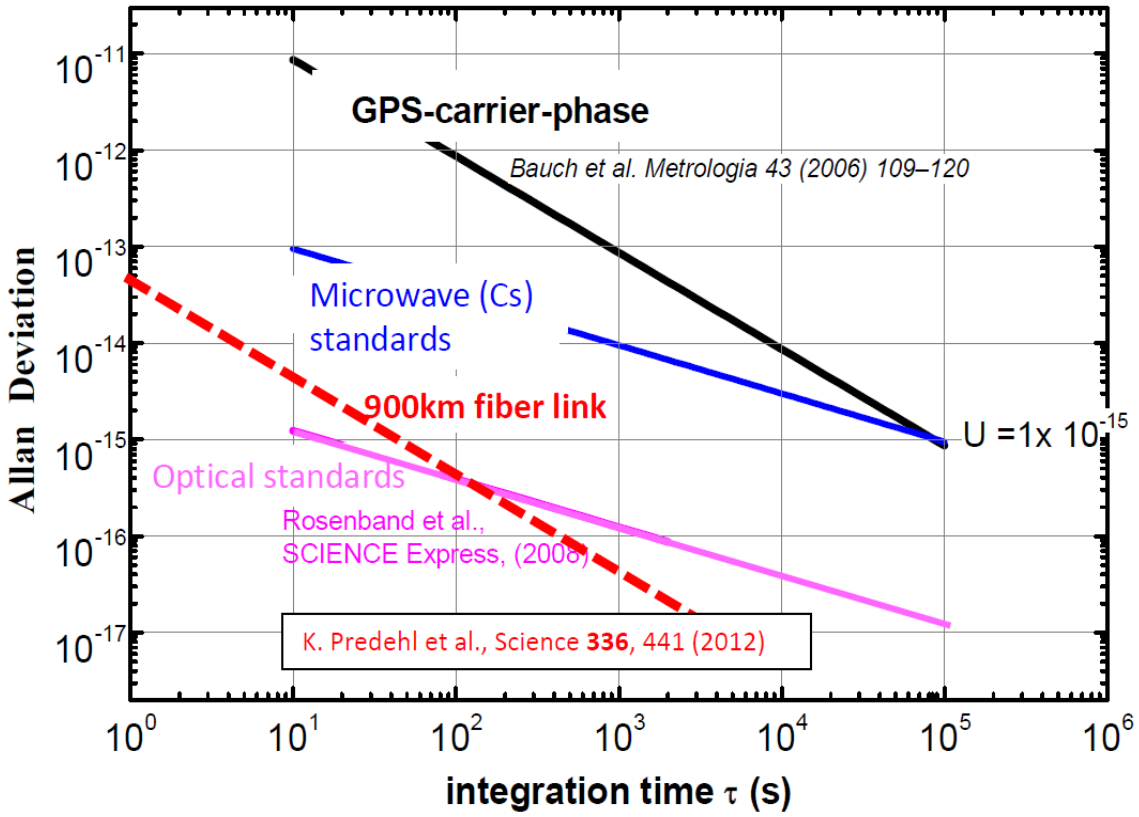
Dissemination T&F

Photo by Jan Huber on Unsplash

Adopted from Wojbor Bogacki talk at PTTI23

Present optical clocks need fibre links





1.7×10^{-16}

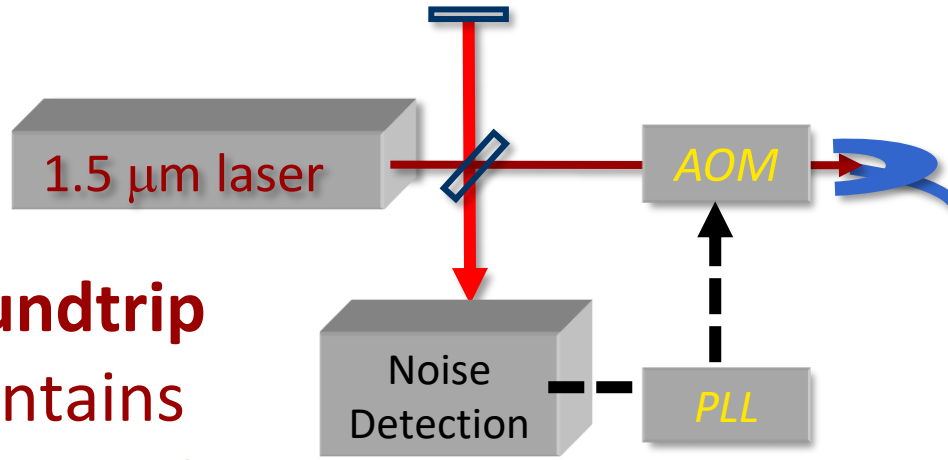
2.1×10^{-18}

[1] S. Weyers *et al.*, Metrologia 55 (2018) 789–805

[2] T.L.Nicholson, *et al.*, Nature Com. 6, 6896 (2015)

Adopted from Harald Schnatz

Present optical clocks need fibre links



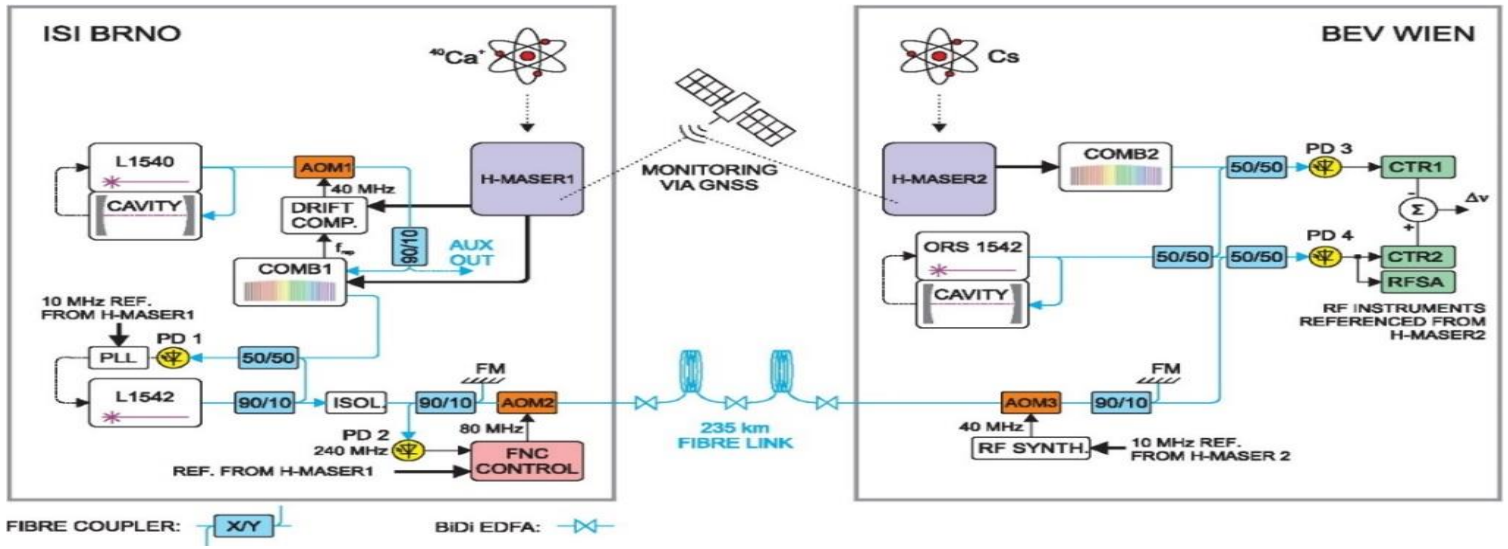
roundtrip contains **2× noise!**

Foreman et al. Rev. Sci Inst. ***78*** *021101 (2007); Williams et al., J. Opt. Soc. Am. B* ***25*** *1284 (2008)…*

1 Optical fiber (~ 1000 km)

Partial reflector

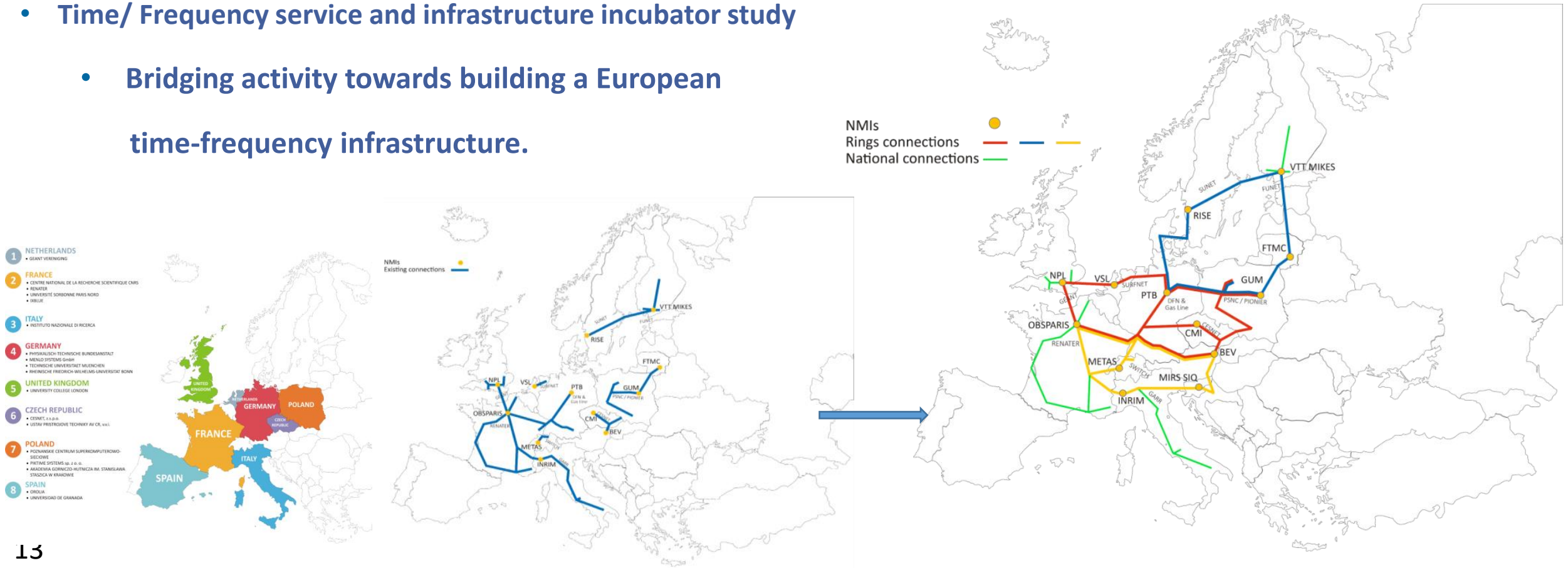
Clock laser + ~~**noise**~~



Cizek et al. ***Opt. Express. 30,*** *5450 (2022)*

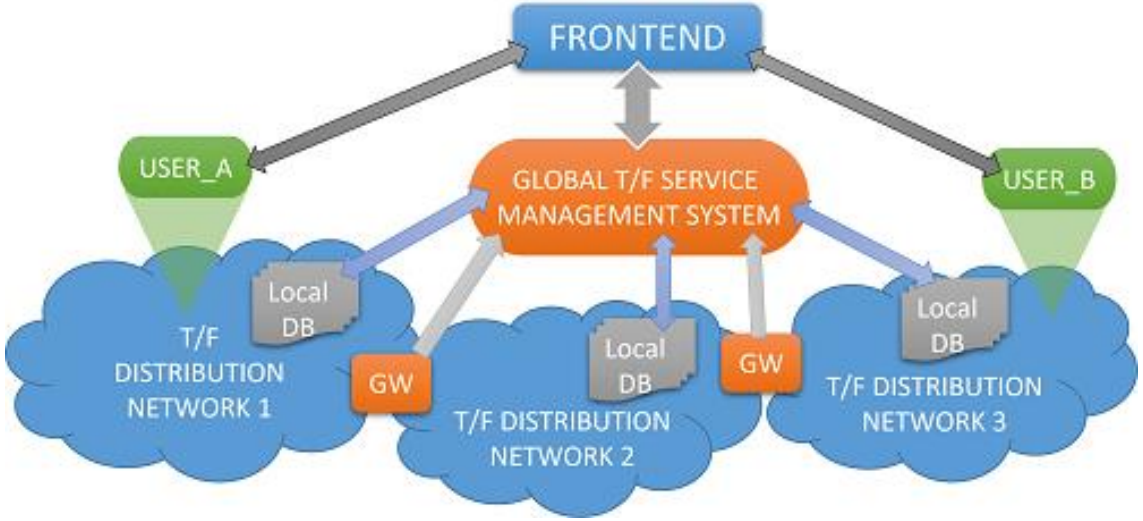
Optical Time and Frequency Networks - OTFN

- Multiple NRENs together with National Metrology Institutes developed and operate OTFN lines already
- CLONETS-DS finished, deliverables on the web: https://clonets-ds.eu/
- GN4-3 WP6 OTFN continues as GN5-1 WP6 OTFN https://wiki.geant.org/display/NETDEV/OTFN
- Time/ Frequency service and infrastructure incubator study
  - Bridging activity towards building a European time-frequency infrastructure.



Optical Time and Frequency Networks - OTFN

- New TF Gateway for NREN support
  - information on TF transfer in Europe (https://wiki.geant.org/display/NETDEV/TF+Gateway)
  - national signal sources
  - cross-border information
- Investigations of monitoring and calibration solutions



Slide kindly provided by Susanne Naegele-Jackson

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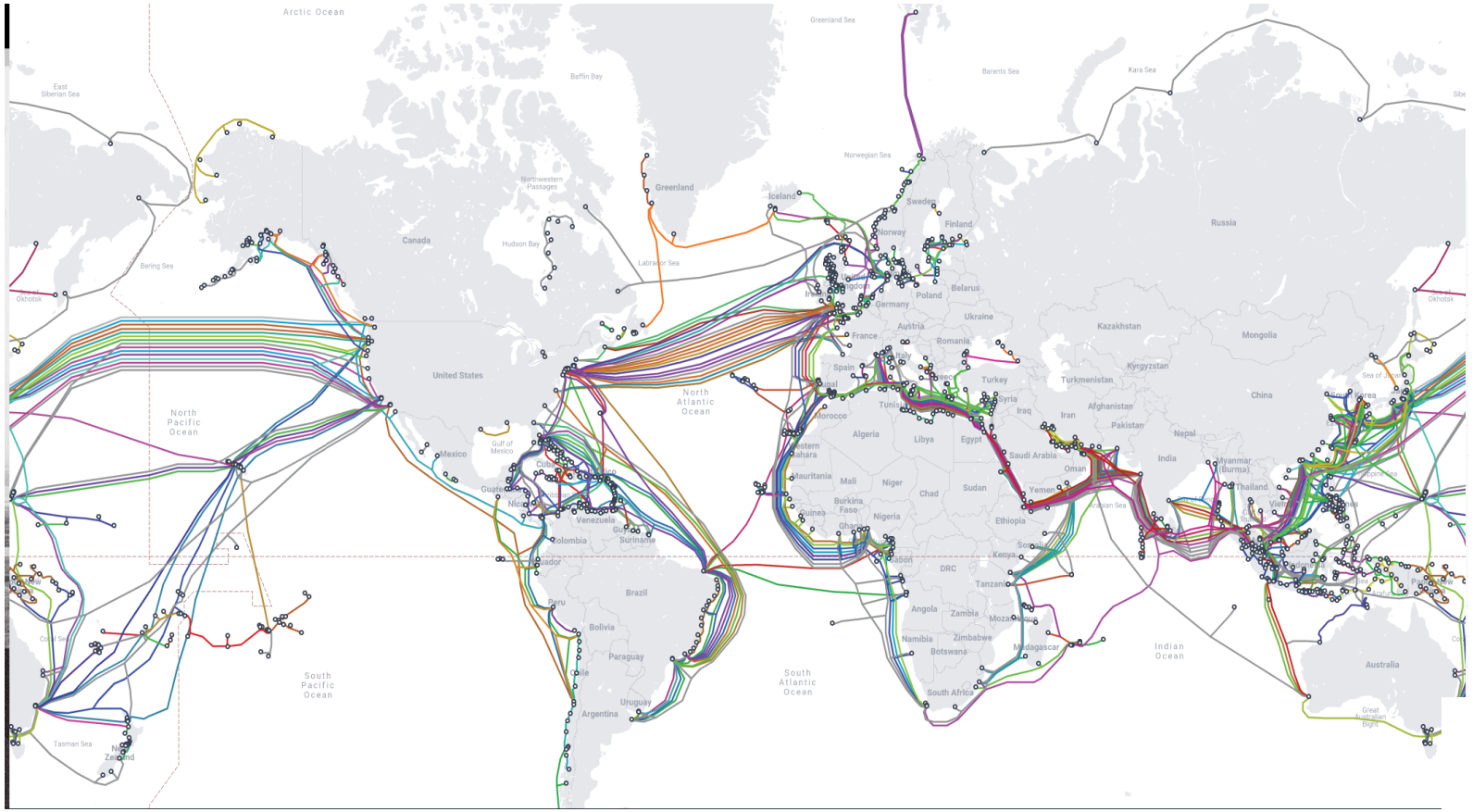
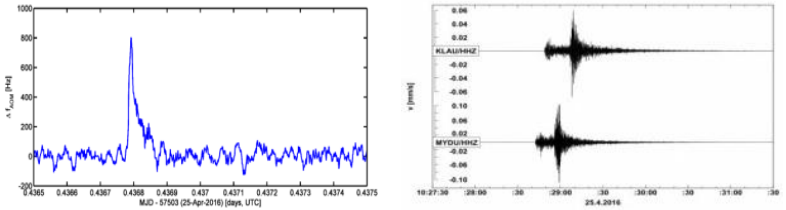
- **(Submarine) Fibre Sensing**

Submarine fiber cables = global sensing network



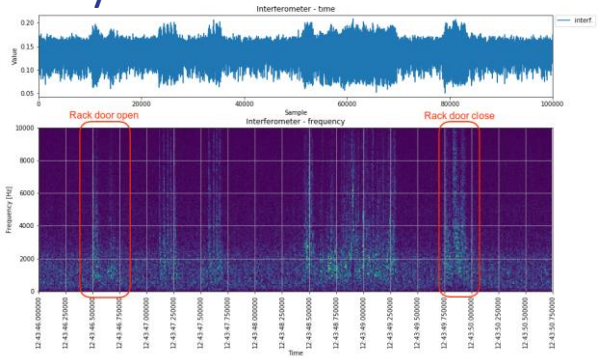
Credit: www.submarinecablemap.com

Interferometry

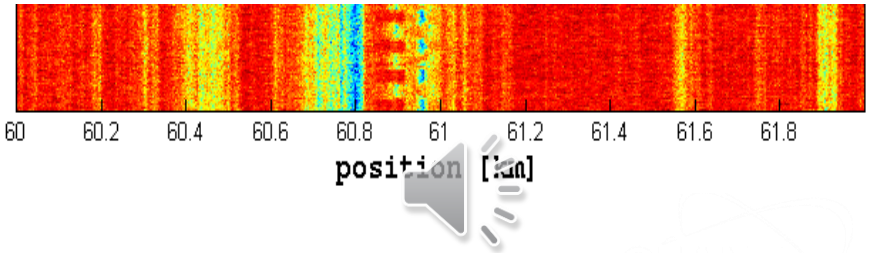


25. Apr 2017 4.1 deg, 20 km SW from Vienna, credit *Cizek M.*

Polarimetry



Phase OTDR - DAS



- **Duration:** 36 months
- **State date:** May 2023
- **Total personnel effort:** 652 Person Months
- 24 partner, including GÉANT and 8 NRENs (FCT, GRNET, Sikt, NORDUnet, CESNET, DeiC, PSNC, GRENA) and EUROPEAN FUTURE INNOVATION SYSTEM CENTRE as Coordinator)
- **Main goal:** Investigate utilising existing telecommunication systems, rather than dedicated submarine fibre, for monitoring the earth and oceans, without disrupting telecoms traffic.

Research Organisations

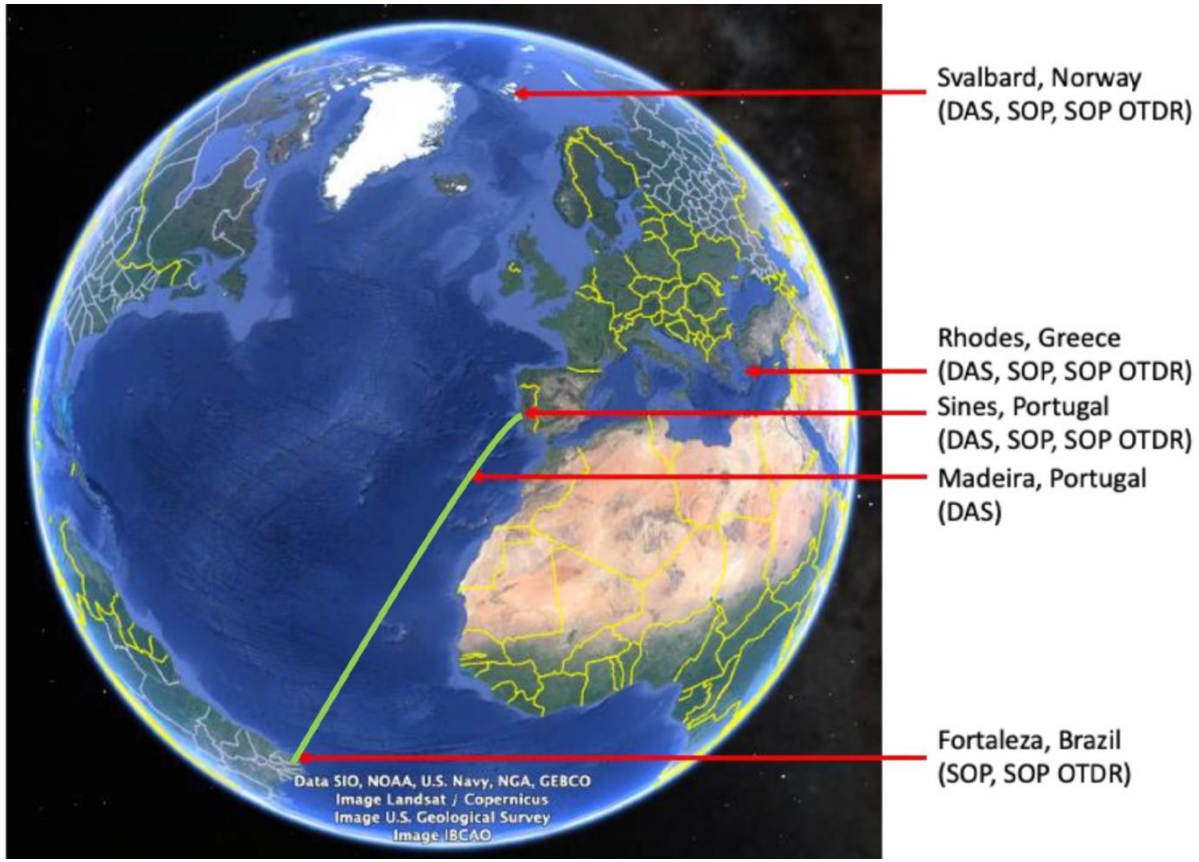
NRENs

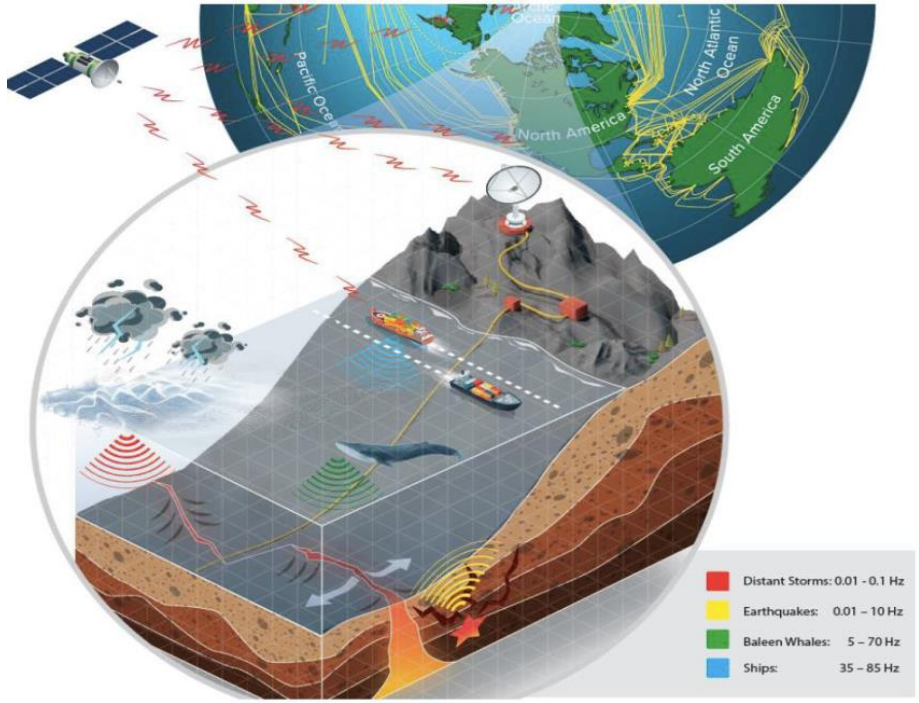
Commercial organisations

Indicative Site Locations

Primary sites would have both DAS, SOP and SOP OTDR

Secondary sites would not have all experiments





What can be detected

- Wales
- Storms
- Ships
- Earthquakes
- And more

Adopted from Chris Atherton slides

Conclusions

- Looking for and open to cooperation and experience exchange in the field with very high dynamics of development
- QT: Gap analysis of future QKD service(s) in GÉANT
- QT: Support of NRENs and their users (hardware, standartization, training)
- OTFN: CLONETS-DS has clearly identified the need for a pan-European time/frequency infrastructure
- OTFN: Time/ Frequency service and infrastructure incubator study develop a business case and sustainability model for constructing a time/frequency network to interconnect European National Metrology Institutes (NMIs) with diverse scientific users
- Sensing: The GEANT community's dark fibre assets will move from being a commodity internet to a scientific instrument
- Sensing: Building a repository of seismic data for science will be a big asset for researchers

Thank You

Any questions?
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www.geant.org

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Quantum training

- Start of series “Quantum Technology” as part of network track in the GÉANT eAcademy in collaboration with GLAD team
- Modules planned on
- Introduction to Quantum Algebra
- Standardisations
- Quantum Communication
- Simulators
- State of the Art reports, …
- https://e-academy.geant.org/

Adopted from Ilias Papastamatiou and *Piotr Rydlichowski talk at TNC23*

Optical Time and Frequency Networks - OTFN

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

- https://events.geant.org/event/451/

GÉANT Infoshare: Management and monitoring of time & frequency services

- https://events.geant.org/event/1207/

Whitepapers:

- Distributing New Performant Time and Frequency Services over NREN Networks

https://www.geant.org/Resources/Documents/GN4-3_White-Paper_Time_and_Frequency.pdf

- Ultrastable Frequency Transfer in L-Band

https://resources.geant.org/wp-content/uploads/2022/02/GN4-3_White-Paper_Ultrastable-Frequency-Transfer-in-L-Band.pdf

- Management and monitoring of time and frequency services

https://resources.geant.org/wp-content/uploads/2022/11/GN4-3_White-Paper_Management-and-Monitoring-of-TF-Services.pdf