Nordic Timing Pilot

Interconnecting Nordic NMIs with a 2700km

White Rabbit Time Distribution Network

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BoF Below the Sky

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tnc26

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NORDIC TIMING SUMMIT

@NORDUnet Community Workshop Sept.2025

A forum for Nordic timing stakeholders

National Research and Education Networks

National Metrology Institutes

& *Time Service Providers*

& Friends

Joint agreement to:

Inspire and incubate policy and action on critical societal challenge

Indentify technical and engineering solutions

Demonstrate service feasibility

Act on low hanging fruits

Regular meetings

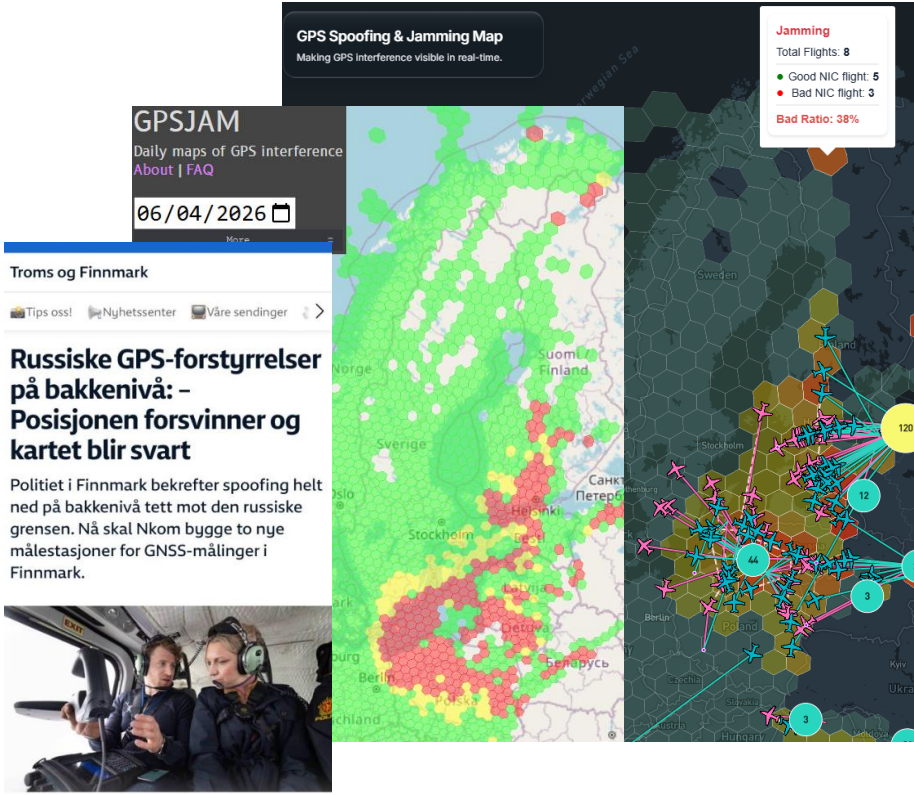
Coordination & collaboration space, agreed meeting schedule

Credit: Lars Fischer NorduNet

Example of use case for terrestrial time service in the Nordics

- Interconnecting Nordic NMIs
  - Interconnecting time laboratories in the Nordics + to mainland (southern) Europe through SURF and future expansion with GEANT
- Redundancy to GNSS for PNT services, e.g. northern NREN connectivity NO-SE-FN

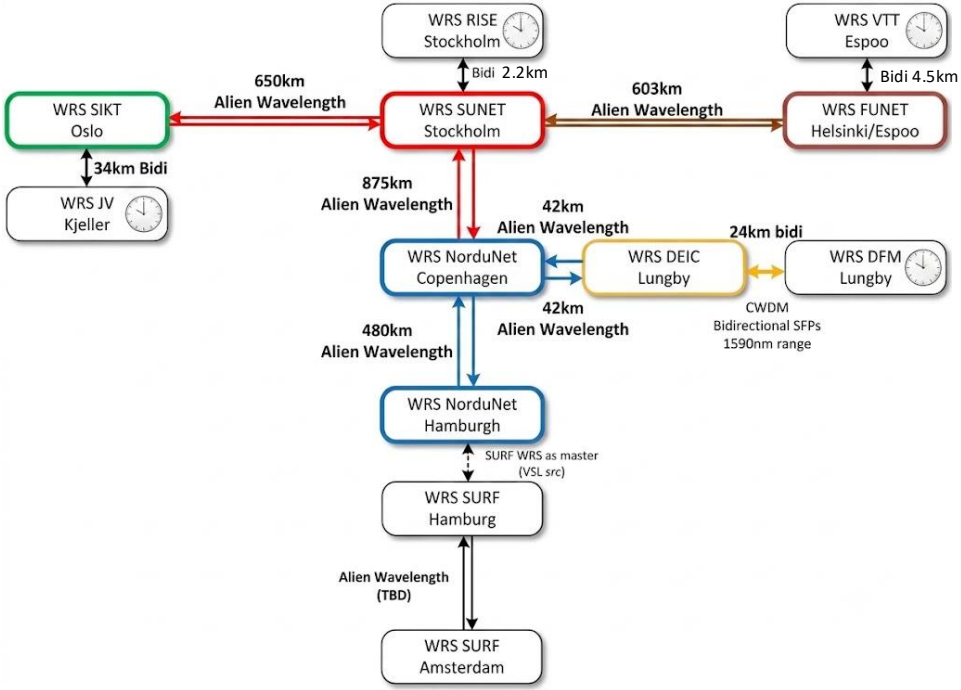
- EISCAT 3D distributed high-powered radar system
  - 3 sites Finland, Norway & Sweden with sub-ns
  - UTC timescale independently & redundant to their GNSS disciplined Rb clock source



Nordic NMIs Interconnectivity Pilot

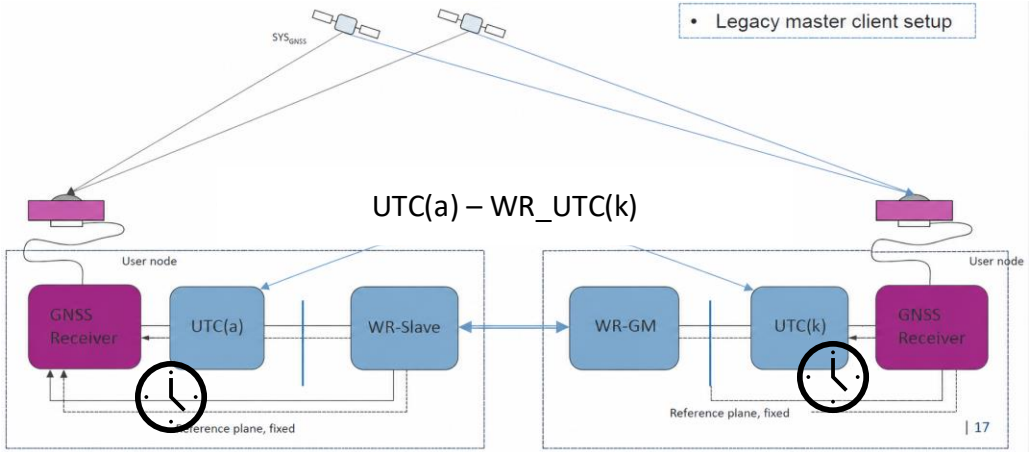
2026 - Phase 1 Unidirectional Backbone & bidirectional edge

1st configuration: UTC(RISE) as clock source (grand master) in the White Rabbit network



> 2700km white rabbit links

1st Use Case – NMI comparing UTC(k) to WR delivered UTC(SP)



Credit: Carsten Rieck, RISE

Additional sources for comparison of UTC(SP), UTC(MIKE), UTC(JV), UTC(DFM):

- BIPM Circular-T – offline comparison of the timescales difference, usually in range of ns(s)
- Satellite-based comparisons, e.g. FUGRO Atomichron service

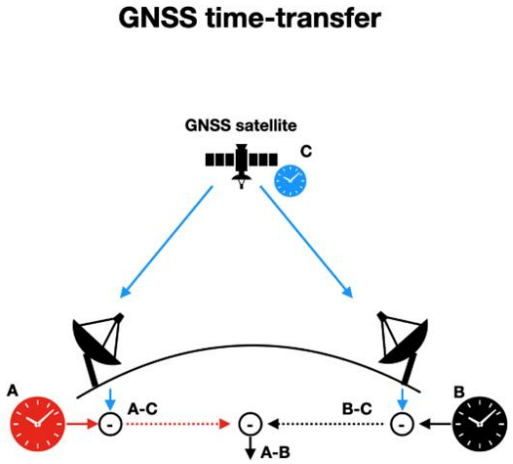


Figure: NIST

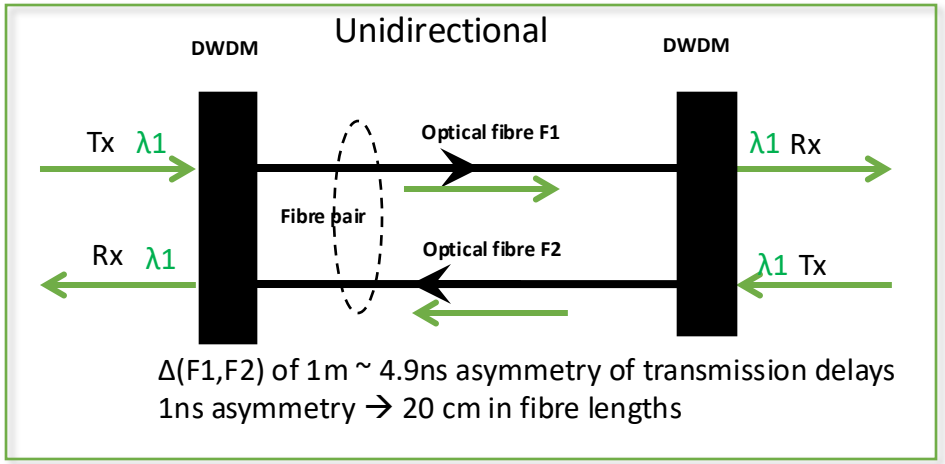
E.g. Common View GNSS Time Transfer

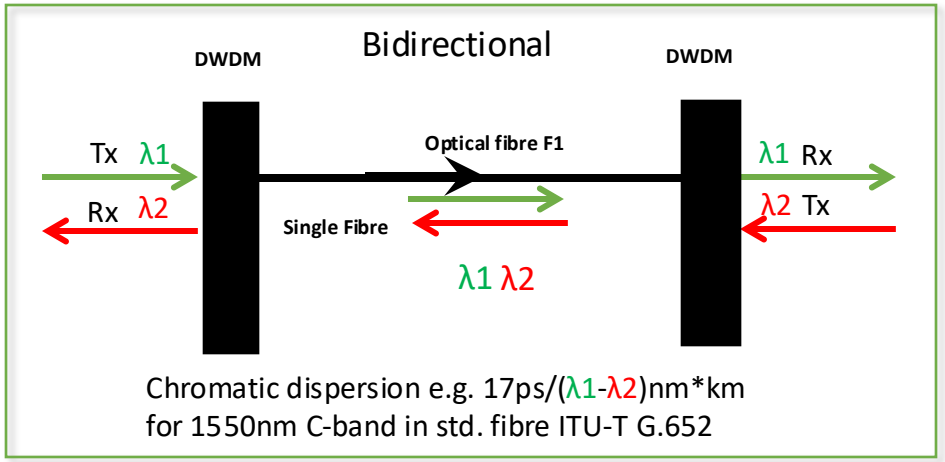
Comparing remote clocks A and B through common GNSS satellite clock C.

Asymmetry Contributors

WR delay link model

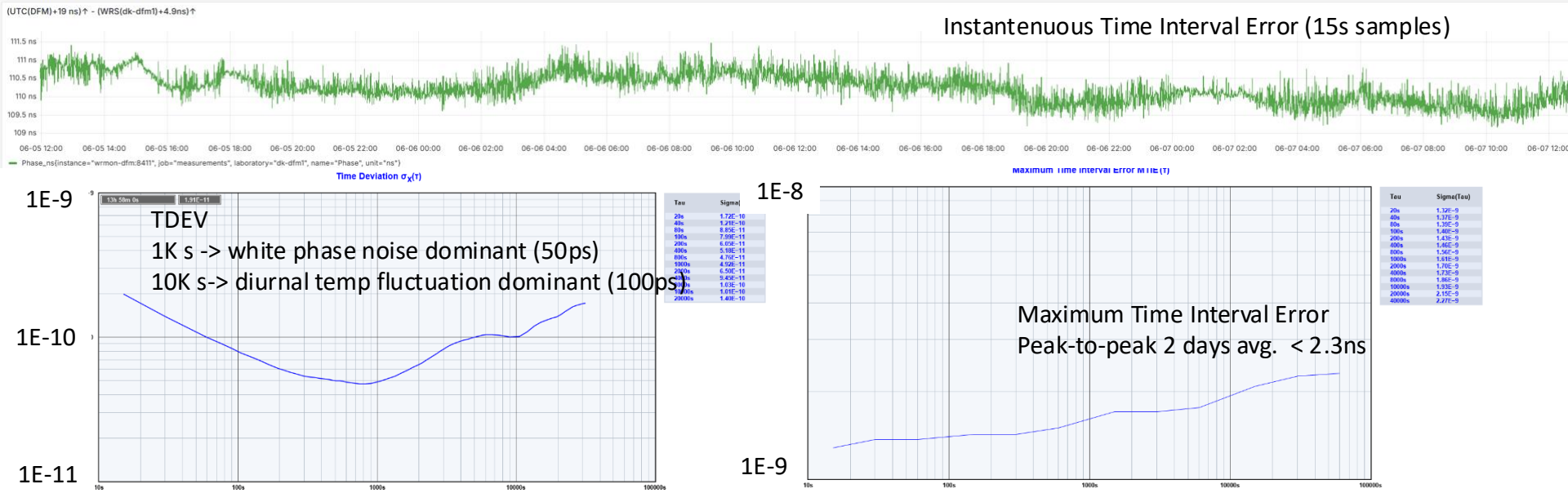
- WR corrects the transmission delay (==RTT/2) asymmetry through calibration
  - Offset error = |asymmetry/2|
- Sources of asymmetry that are calibrated
  - Fixed delay sources: FPGA, PCB, SFPs, OEO
  - Variable delays: fibre(s) delays Tx and Rx
- Unidirectional link adds asymmetry from fibre lengths in the pair
  - Variable after each fibre maintenance (variable monthly/quarterly, yearly?)
- Bidirectional link introduces asymmetry from chromatic dispersion dependent on wavelengths and fibre type
  - Compensated with calibration “once”
  - The standard WR model (CERN)





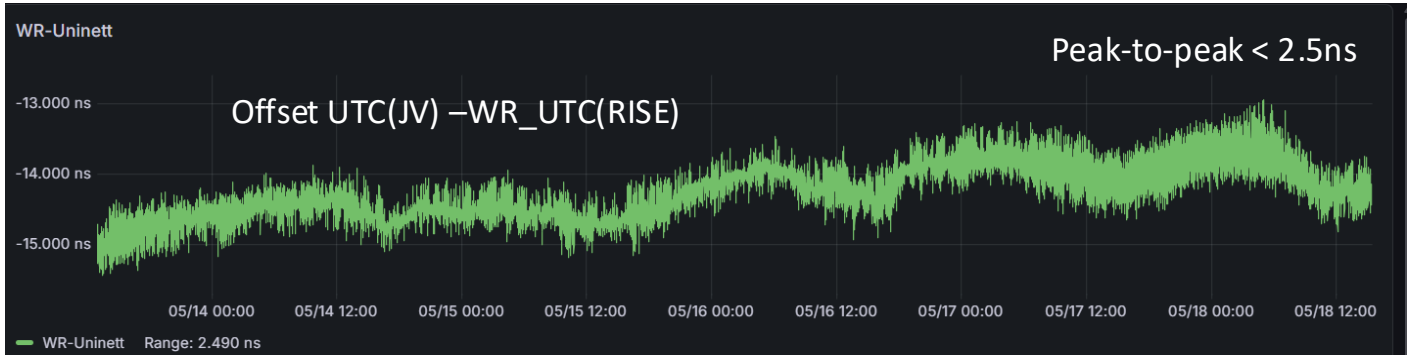
Preliminary Results: Sweden → Danmark

- 5 WR nodes and 945km end-to-end, SUNET alien wavelength with 15 ILA/ROADM sites Stockholm-Copenhagen
- Offset UTC(DFM) – WR_UTC(SP) ~ 97ns range (w/o RF cable delays)
  - 2 Day measurements (06.06-08.06)

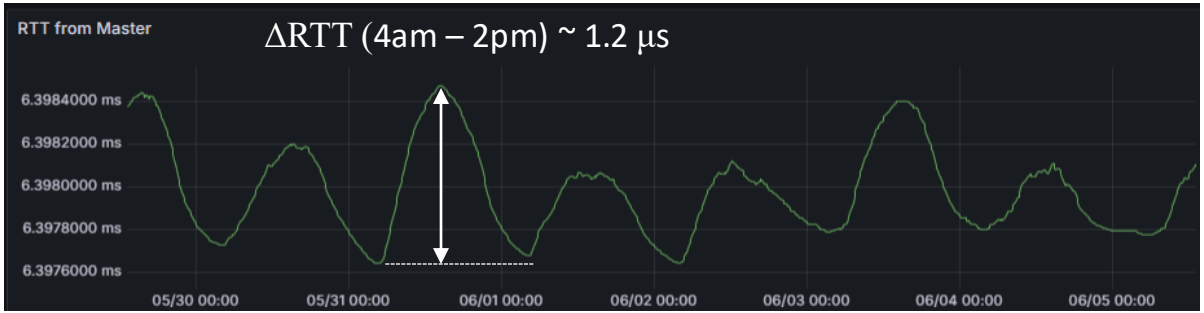


Preliminary Results: Sweden → Norway

4 WR nodes and 686km end-to-end, SUNET alien wavelength through 12 ILA/ROADM nodes



Offset ~14ns range
Are asymmetries cancelling each other out?



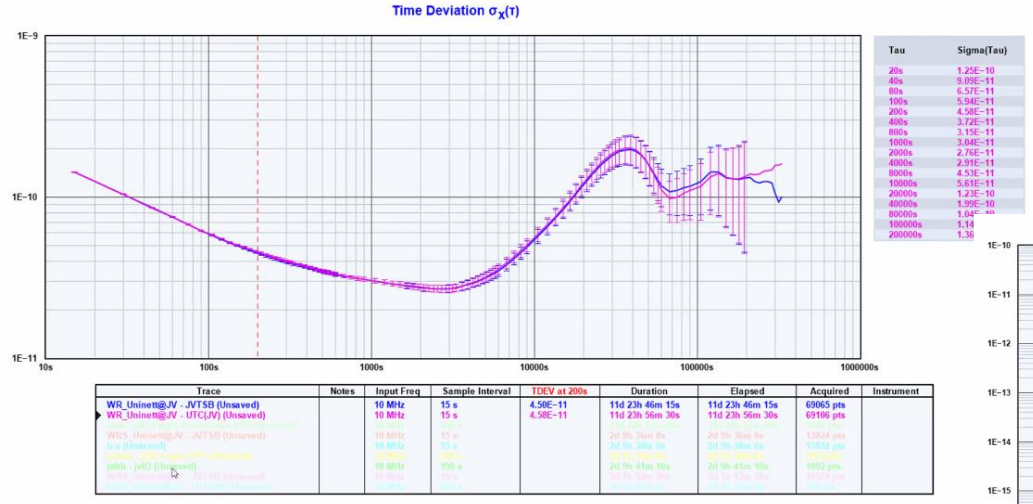
Stockholm – Oslo fibre pair is mainly aerial on power lines

- Daily temperature fluctuations influencing RTT and offset (e.g.@1550nm ~40ps/km/°C)
  - Round trip time 4pm – 2pm ~ 1.2µ s

Note that the graphs are only examples, taken at different days

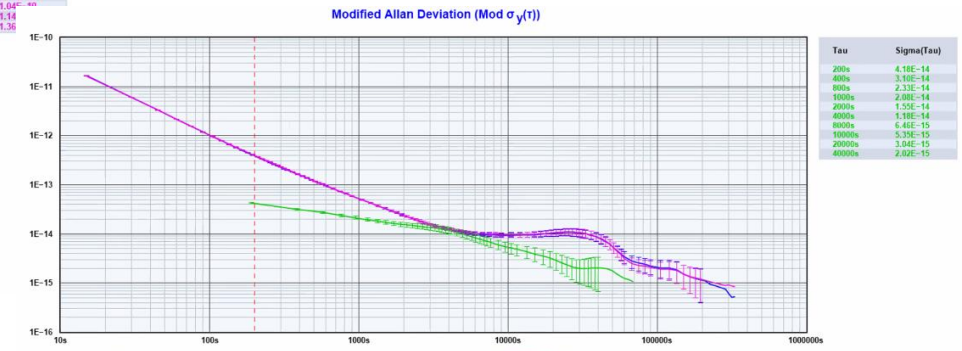
Preliminary Results: Sweden → Norway

- Diurnal temperature fluctuations clearer on TDEV 10ks ~60ps



Tau	Sigma(Tau)
20s	1.25E-10
40s	9.09E-11
80s	6.57E-11
100s	5.94E-11
200s	4.58E-11
400s	3.72E-11
800s	3.15E-11
1000s	3.04E-11
2000s	2.76E-11
4000s	2.91E-11
8000s	4.53E-11
10000s	5.61E-11
20000s	1.23E-10
40000s	1.99E-10
80000s	1.04E-
100000s	1.14
200000s	1.36

Trace	Notes	Input Freq	Sample Interval	TDEV at 200s	Duration	Elapsed	Acquired	Instrument
WR_Uninett@JV - JVTSB (Unsaved)		10 MHz	15 s	4.50E-11	11d 23h 46m 15s	11d 23h 46m 15s	69065 pts	
WR_Uninett@JV - UTC(JV) (Unsaved)		10 MHz	15 s	4.58E-11	11d 23h 56m 30s	11d 23h 56m 30s	69106 pts	
WRS_Uninett@JV - JVTSB (Unsaved)		10 MHz	15 s		2d 9h 36m 0s	2d 9h 36m 0s	13824 pts	
b-a (Unsaved)		10 MHz	15 s		2d 9h 36m 0s	2d 9h 36m 0s	13832 pts	
ptbb - jv03 (Unsaved)		10 MHz	190 s		2d 9h 41m 10s	2d 9h 41m 10s	1093 pts	
WRS_Uninett@JV - JVTSB (Unsaved)		10 MHz	15 s					



Tau	Sigma(Tau)
200s	4.18E-14
400s	3.16E-14
800s	2.33E-14
1000s	2.08E-14
2000s	1.55E-14
4000s	1.18E-14
8000s	6.46E-15
10000s	5.35E-15
20000s	3.04E-15
40000s	2.02E-15

Trace	Notes	Input Freq	Sample Interval	MDEV at 200s	Duration	Elapsed	Acquired	Instrument
WR_Uninett@JV - JVTSB (Unsaved)		10 MHz	15 s	3.90E-13	11d 23h 46m 15s	11d 23h 46m 15s	69065 pts	
WR_Uninett@JV - UTC(JV) (Unsaved)		10 MHz	15 s	3.97E-13	11d 23h 56m 30s	11d 23h 56m 30s	69106 pts	
WRS_Uninett@JV - JVTSB (Unsaved)		10 MHz	15 s		2d 9h 36m 0s	2d 9h 36m 0s	13824 pts	
b-a (Unsaved)		10 MHz	15 s		2d 9h 36m 0s	2d 9h 36m 0s	13832 pts	
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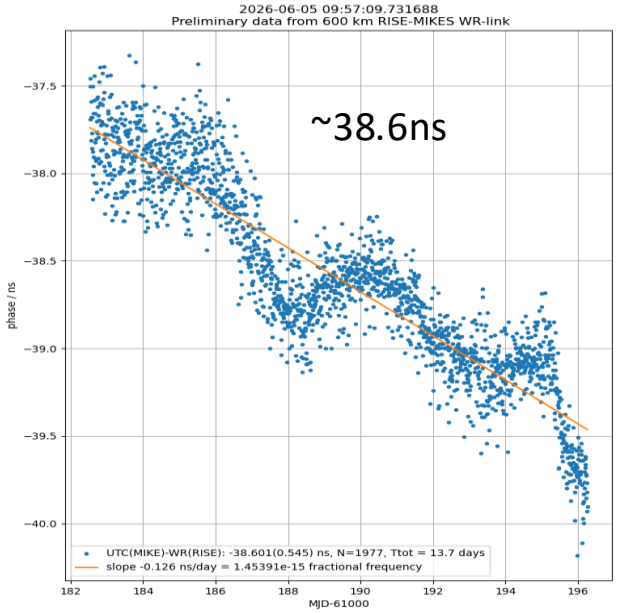
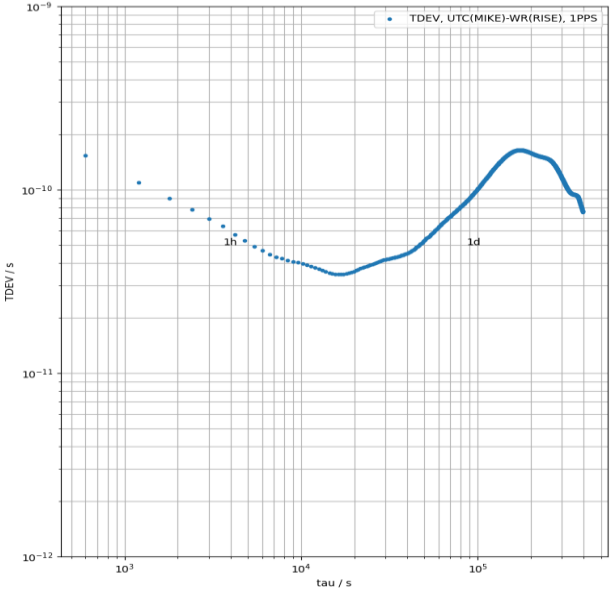
Preliminary Results Sweden → Finland





Further analysis and investigation required

- Temperature fluctuations
  - VTT (submarine) lower than JV (aerial)?
  - Correlate with RTT diurnal variation and find a compensation scheme?
  - downwards trend through 13 days. Monitor for longer periods (months)?

My takeaways:

- Unidirectional transmission/alien wavelengths service:
  - could be an **interim solution** for fast rollout of time services in small scale
  - fibre length asymmetry is “unknown” and can vary from a few to 100s of nanoseconds
    - We can characterize it “once” but it will change with every change of the fibre infrastructure
    - Will propagate depending on where in the WR tree topology the break is
  - NMIs are important partners with the knowledge and infrastructure to help us NRENs with time service performance measurement, (re)calibration and verification.
- Bidirectionality in transmission is **essential** for high performance, stability and ease of operation

NTS next activities:

- Interconnecting SURF delivering UTC(VSL) in Hamburgh
- Delay monitoring White rabbit feature
  - Compare multiple timescales on a WR switch
  - Hop-by-hop measurements for better understanding the time service accuracy in the network
- Further expansion in the network in the nordic fibre links. Redundant links?
- Bidirectionality in the backbone NTS pilot?!

Thank you

Any questions?

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