Planning Country-wide WR Infrastructure

Josef Vojtech

CESNET
Czech Republic

GN5-1 infoshare
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Credits

Ondrej Havlis, Vladimir Smotlacha, Martin Slapak, Radek Velc

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CITAF

Czech Infrastructure for Time and Frequency

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CITAF

- To be a national platform for cooperation in research and development of methods of time and frequency transmission in optical networks;
- To establish a permanent national optical infrastructure for the transmission of time and frequency and interconnect it to the follow-up European infrastructure;
- To support joint publishing activities of partners and cooperation in national and international projects and grants;
- Present the results of cooperation and develop an awareness of the possibilities and use of the distribution of very accurate time and stable frequency.

ÚFE

CTU CZECH TECHNICAL UNIVERSITY IN PRAGUE

ISI CAS

FJFI

IPP

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CITAF has currently 6 partners

- three institutes of Academy of sciences
- two faculties of public university
- CESNET

http://citaf.org

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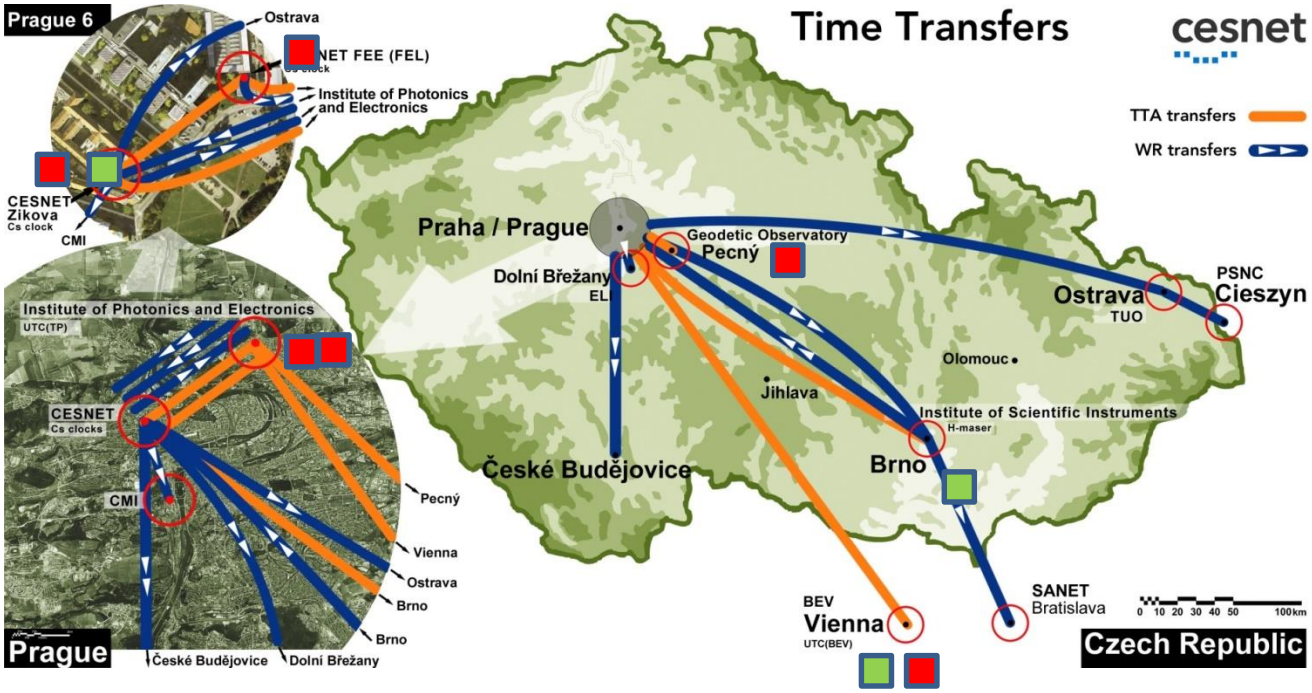
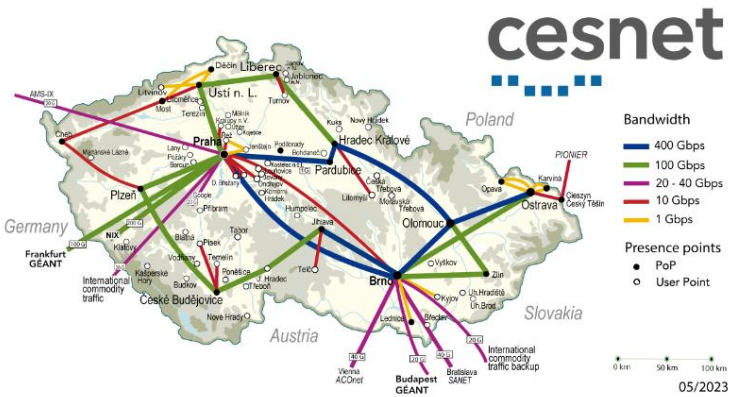
Time and Frequency Distribution in CESNET Network

Infrastructure for Time and Frequency

- **Precise time transmission over 2200+ km**





Time Transfer Adapters

Own developed, FPGA based TDEV ~ 20-30ps

White Rabbit

Commercially available, based on CERN OHWR project

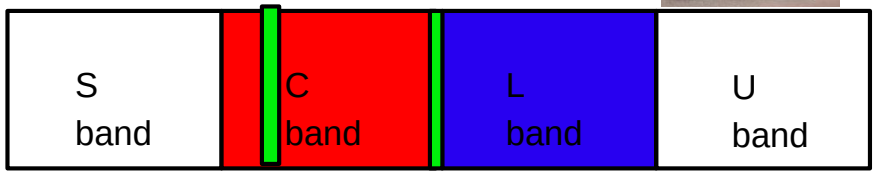
Cs clock 5071A

Active H maser

Time and Frequency Service

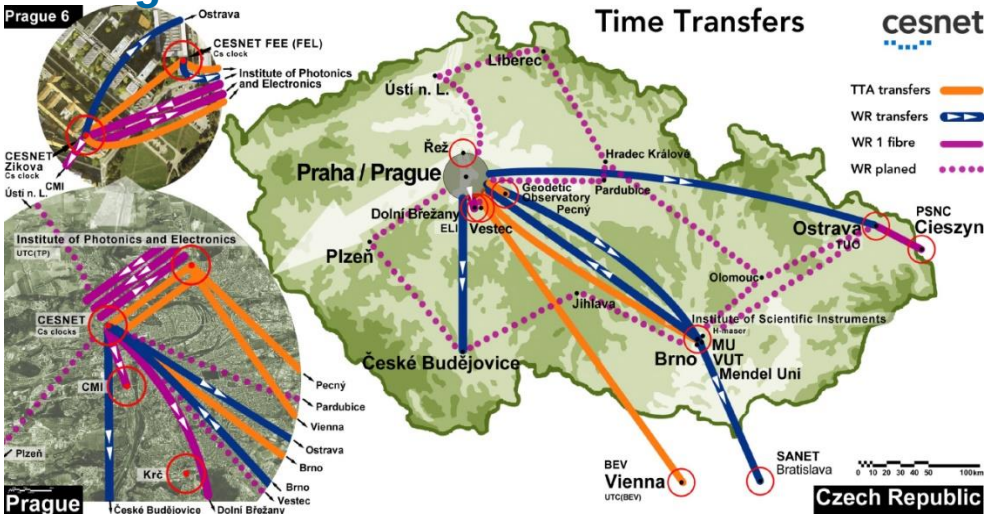
Goal: provide accurate TF service over whole CESNET network

- Service to be available in nodes with an university or research institute
- White Rabbit technology chosen
- Operate a reliable distributed WR system is a challenge
  - monitoring
  - resilience



Available network infrastructure

- Bidirectional transfer over dedicated channel in commercial DWDM
- Bidirectional amplifiers in telecom huts



Standard WRS

- https://white-rabbit.web.cern.ch/

- **Possible modes: BC (boundary clock), GM (grand-master), FR (free running)**
- **Modes are configurable but fall down to FR in case of reference issue**
  - Sometimes do not return back to BC / GM
- **No direct indication of mode or mode change (i.e. LED change)**
- **No standard utility to announce mode**
  - Utility wr_mon displays mode, however runs continuously, unsuitable for a parsing script
- **Mode and other running parameters available in /proc or accessible by SNMP**
- **Result: own utilities should be written to know the WRS status**

White Rabbit Switch

Main issues of standard WRS

- Only one port port might be configured as slave
- Identification of network failure requires active monitoring
- Box reconfiguration in case of lost reference
- Occasional freezing (no clear dependence on noisy signal)

Solution: Avoid standard WRS in critical applications

Commercial producers offer WR boxes with advanced resiliency (compared to CERN design)

White Rabbit with Multi-source Reference

WR boxes with several reference inputs

- **Specified priority of Inputs**
- **Automatic switching to another input in case of signal failure**
- **Recovery once higher priority signal is available again**
- **Switching as fast as possible**
  - No box with immediate switching yet available ??

WR-Z16

Example: WR-Z16 from Safran / SevenSolutions

- two reference SFP ports
- 1PPS / 10 MHz inputs
- input switching takes tens of seconds

- **Do you utilize other WRS with multi reference?**

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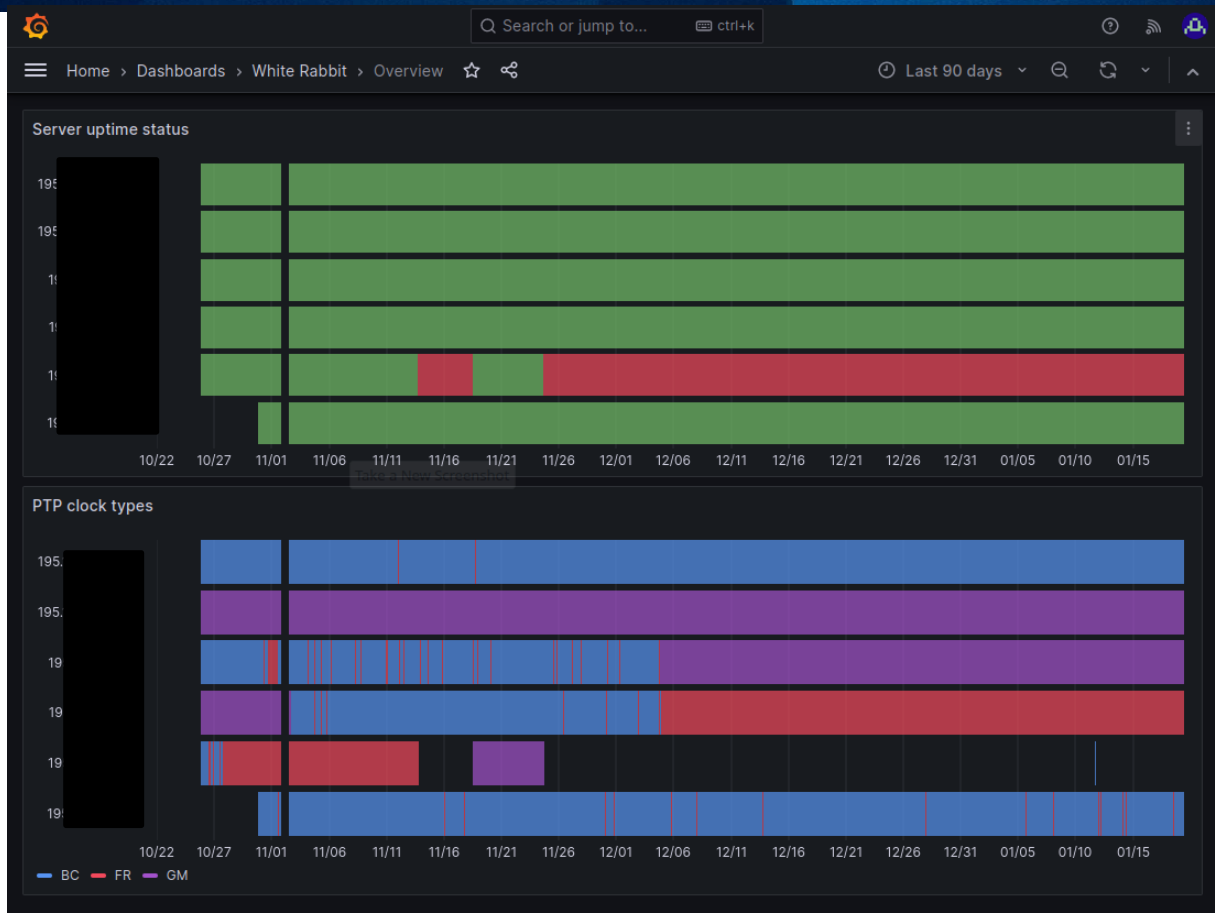
White Rabbit monitoring

WRS monitoring

White Rabbit monitoring system

- **Remotely called scripts**
- **SNMP polling**
- **Presentation layer in Grafana**
  - General overview of mode
  - Status details
- **Supports both WRS and WR-Z16**



WRS monitoring

WRS box details

- Mode
- Port status
- Rx and Tx power
- SFP temperature

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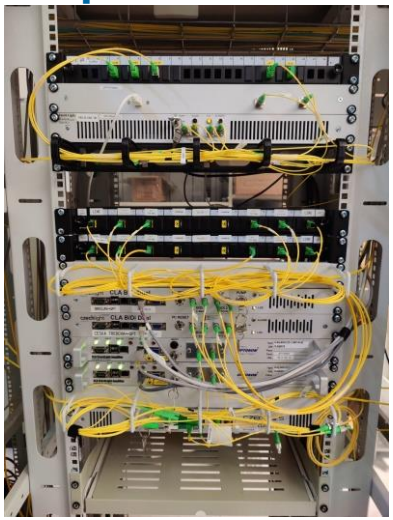
Bidi Amplifiers for WR

BiDi Optical Amplifiers

Bidirectional optical amplifiers

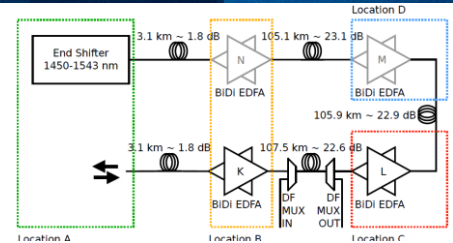
- WR runs over single fiber -> bidi amplification preferred
- control and monitoring of amplifiers is necessary for reliable WR operation – avoiding lasing etc.
- Signifficant increase

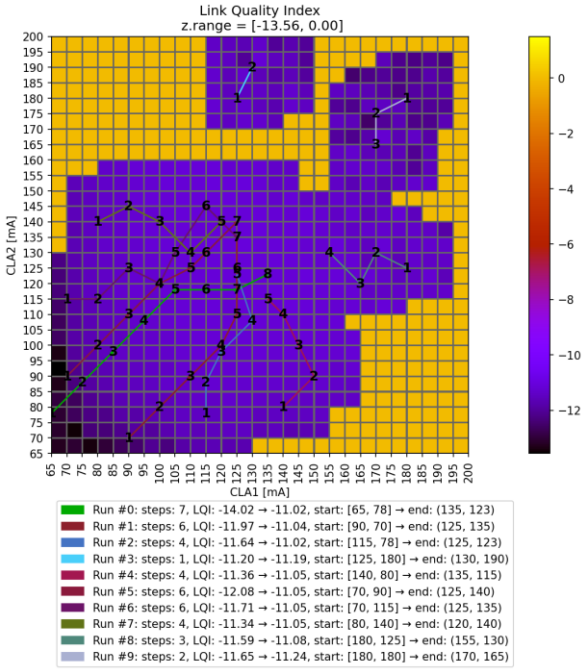
  30 to about 70 devices



BiDi Optical Amplification

- Hi gain medium + feedback - we are trying to avoid it!! $G^2R_1R_2 << 1$
- R composes from Rayleigh backscattering and reflections from splices, connectors etc.
- Only with limited gain up to 20-21 dB
- Signal levels has variations (PDL, PDG)
- Reflectivity is changing (service works)
- CESNET developped LiPoBa2 - Lasing detection and avoidance throughbidi gain balancing
- Works for coherent optical frequency, now.





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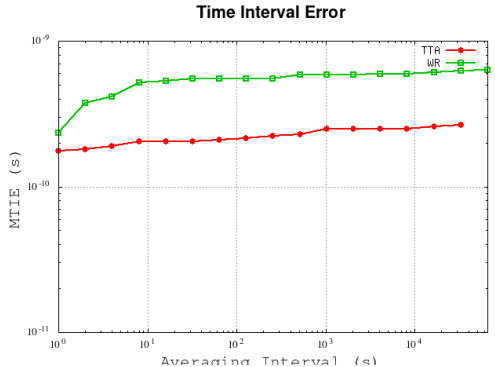
THANK YOU

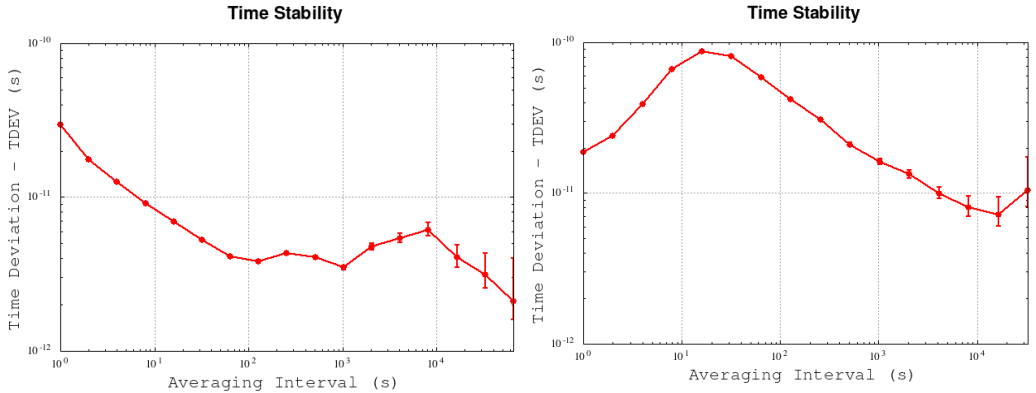
Time and Frequency Service

- (Cs clock generated) time scale comparison using multiple optical methods deployed
  - TTA + WR
    - CESNET – IPE
    - FEE CTU – IPE

Details: Smotlacha V., Vojtech J., EFTF 2022



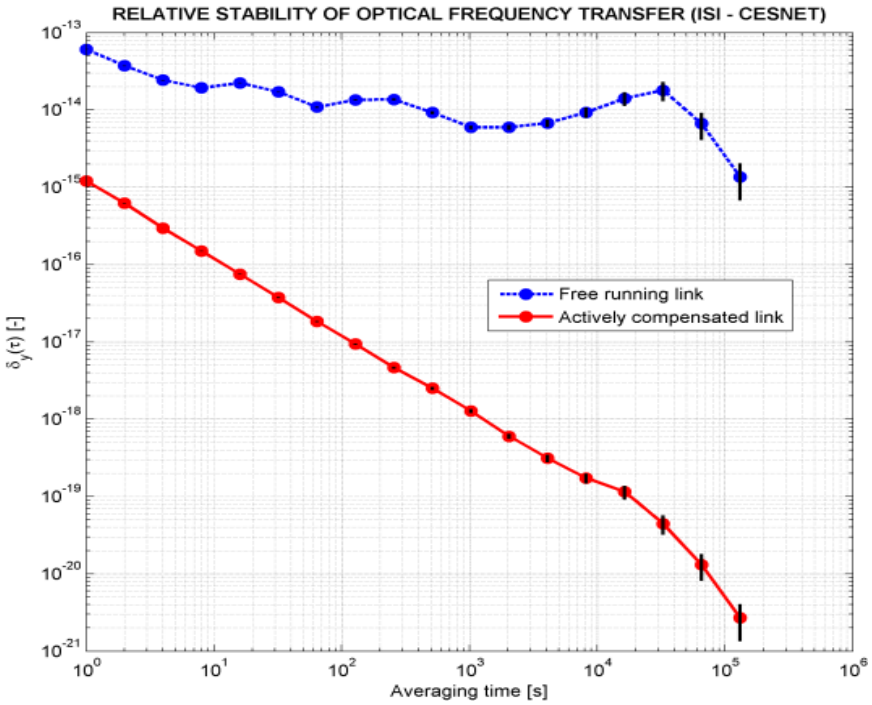
Comparison of Maximum Time Interval Error



TDEV comparison for TTA and WR transfers over 180 km of field deployed fibre

Optical Frequency Transfer

- Frequency transfer started in 2015, now at 1100+ km of fiber, about 30 bidi amplification nodes
- Interconnection of (being developed) optical clocks based on Ca+ ion
- Signals carried: sub Hz narrowed lasers at 1540.5 nm and 1542.1 nm. 1458 as half frequency of Ca+ transition
- Bandwidth for 1572 nm reserved



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

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SENSING ACTIVITIES

Polarization sensing

Request of passive sensing on majority of fibers

- **Core backbone operate PolMux coherent data transmission only**
  - Unsuitable for polarization sensing using polarimeter
- **WR channel non-coherent**
  - Option for polarization sensing

Vibrations/Tampering with Fibre Detection

- Polarimetry
- Needs only passive (e.g. WR) signal for listening
- CW laser used for better stability in figure
- Developed Polarilog devices to be deployed on submarine cables in NO, PT, IT, GR within Horizon Europe project SUBMERSE (https://submerse.eu/)