WHITE RABBIT OVER COHERENT NETWORK IN CITAF

Josef Vojtech et al.
Optical networks department, CESNET, Czech Republic

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GÉANT Infoshare on Management and monitoring of time & frequency services

Credits

- Lada Altmannova, Ondrej Havlis, Tomas Horvath, Vladimir Smotlacha, Martin Slapak, Radek Velc
- Jakub Mer, Martin Michal

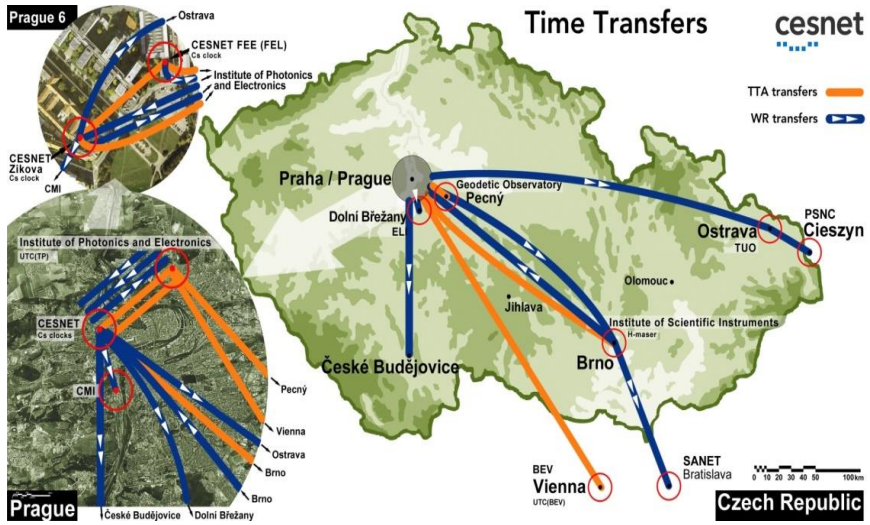
Introduction

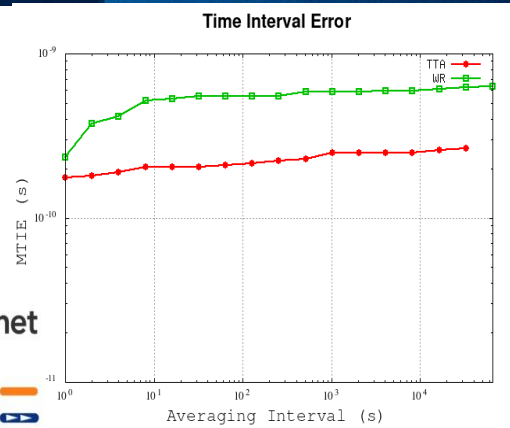
- CITAF (precise time transmission with White Rabbit)
  - Fibre Sharing
- Problem Source Identification
- Simulations
- Verification in Live Network

CITAF Infrastructure

- Bidi transmission + legacy unidirectional telecom lambdas
- Time+RF – Time Transfer Adapters + White Rabbit
  - White Rabbit - 1800 km of transmission
- Massive shared with data (to avoid extra fibre rental fees)
- Comparison of UTCs
  - UTC(TP),UTC(BEV),
  - ongoing UTC(PL)
- Distribution
  - ELI, TUO, UoSB
- Connected Cs and H maser public operators

Toward to Synthetic Time Scale

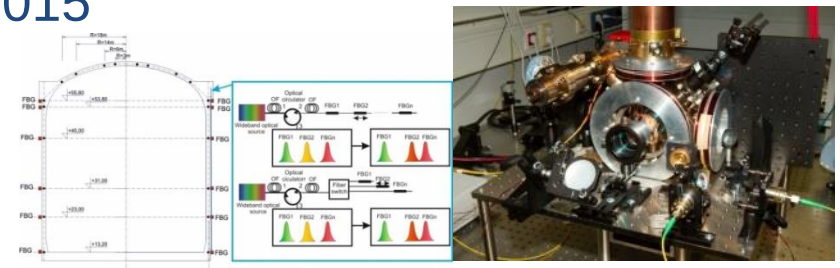


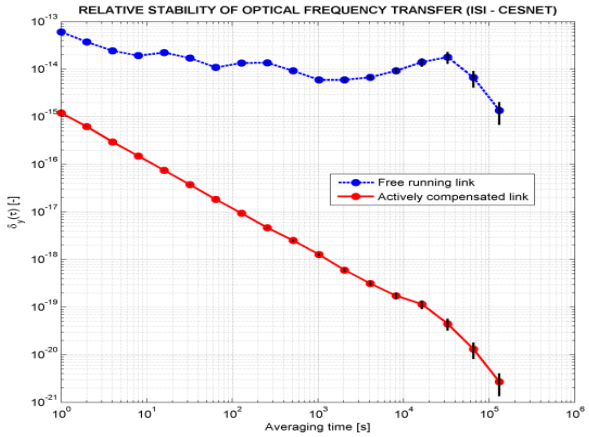


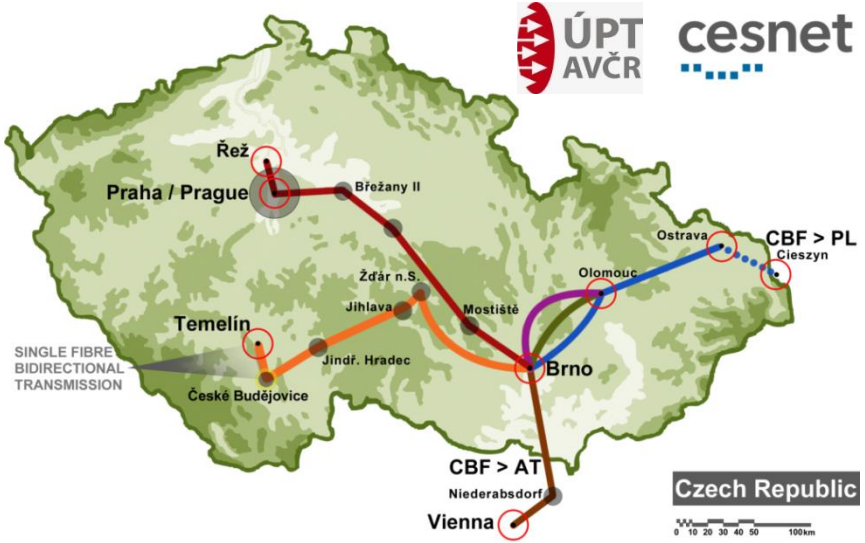
Performance over bidir field deployed fiber loop (96 km, attenuation 24.6 dB)

Coherent Optical Frequency

- Coherent optical frequency – COF bidirectional transmission within single fibre: +1100 km, since 2015
- Dual window (ch 44+46 and ch 7) OADMs
  - Optical frequency transport for nuclear reactor
  - Interconnection of Ca+ based optical clocks



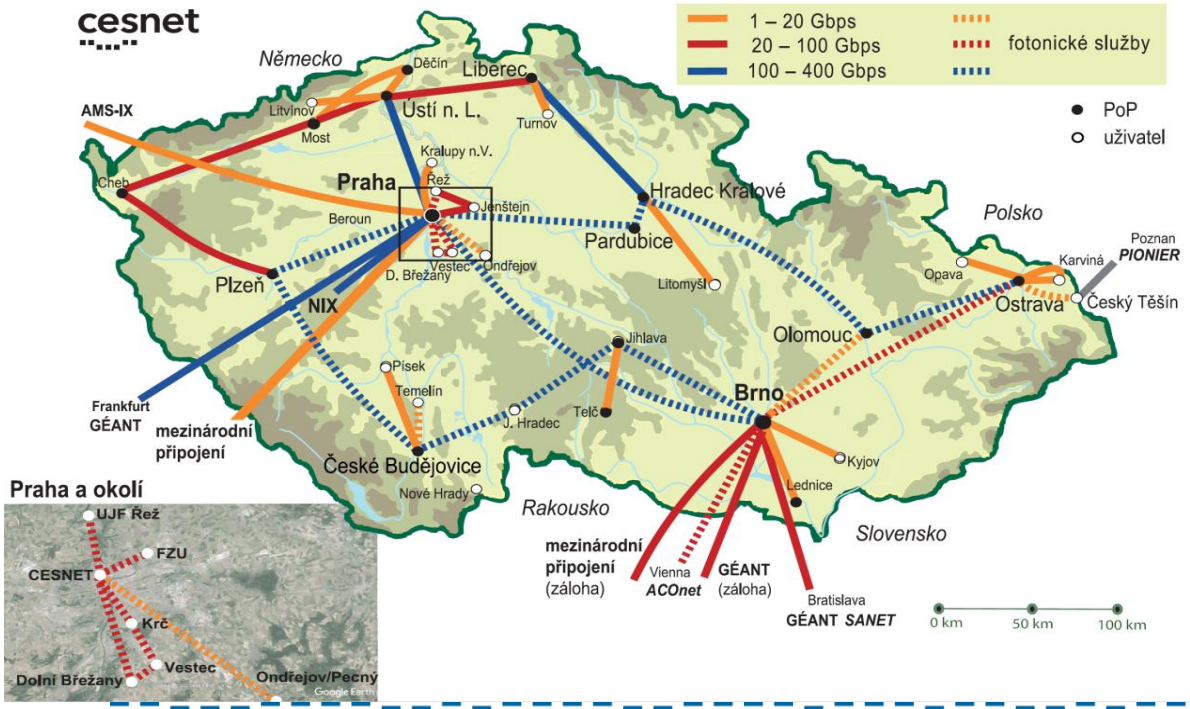




CESNET Praha - UPT Brno 306 km, instability 10^{-18}

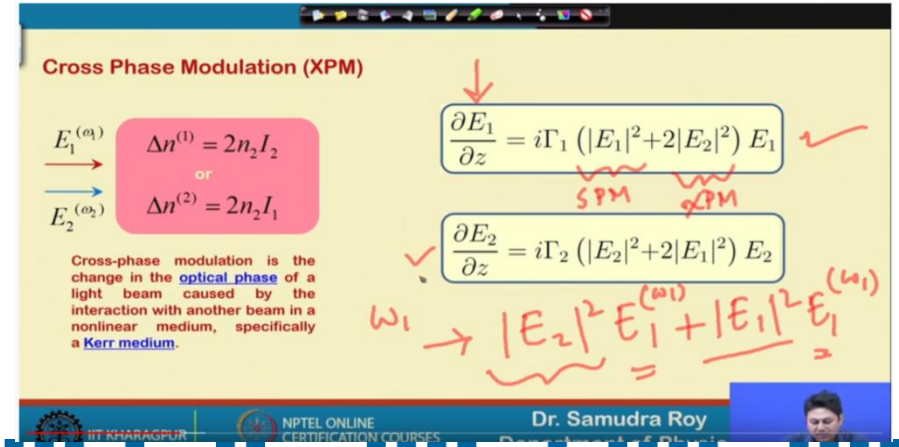
Spectrum Sharing

- 120+ dual band OADMs deployed into major lines
- Major lines carry 400 and 100 G traffic
- Dotted lines on map are shared



Source of Problems

- χ^3 - nonlinearity of third oder in fibers (SPM, XPM, FWM - Self Phase Modulation, Cross Phase Modulation, Four Wave Mixing)
- SPM, XPM – via refractive index modulation
- Lecture 47, 48: Third Harmonic Generation (Cont.), Cross Phase Modulation (XPM) https://www.youtube.com/watch?v=LQfqApLtt2I
- Lectures 49,50: Four Wave Mixing https://www.youtube.com/watch?v=aJ3ymzEdKPE
- Foundation of nonlinear optics https://www.youtube.com/watch?v=jbzx-4L4W1s

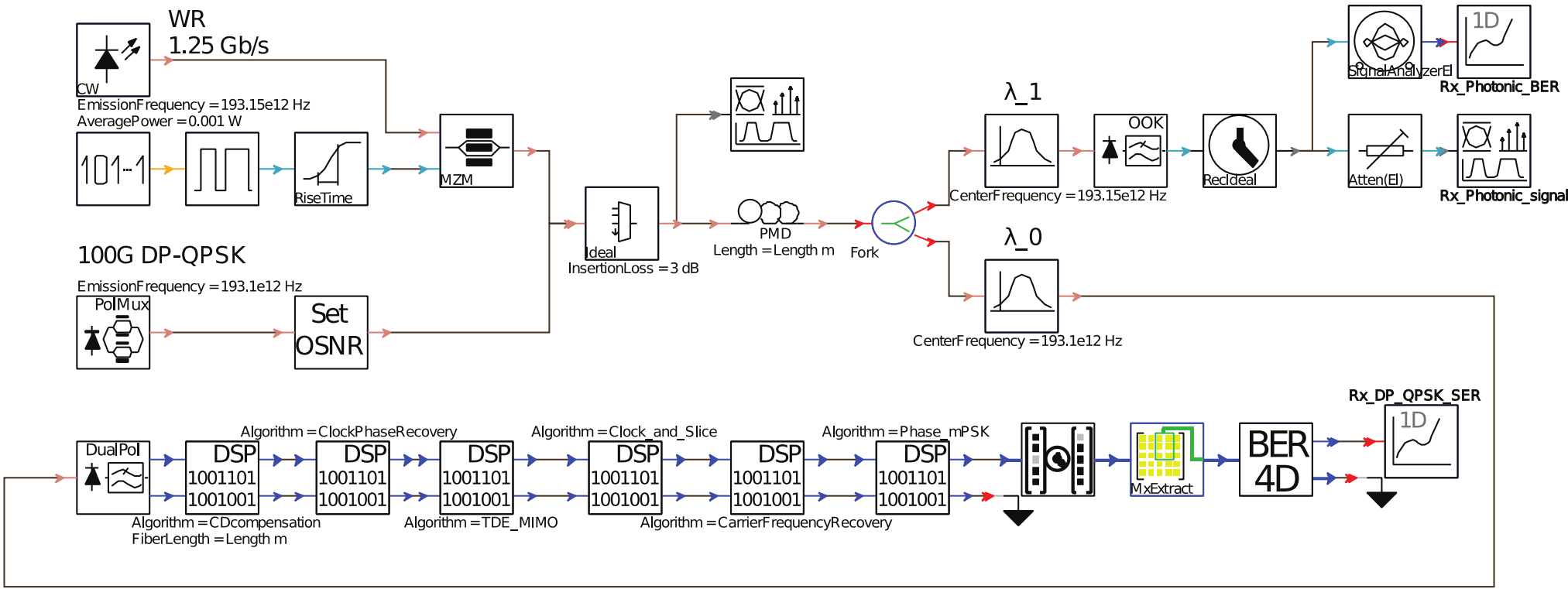


Credit to: Dr Samundra Roy

Simulations

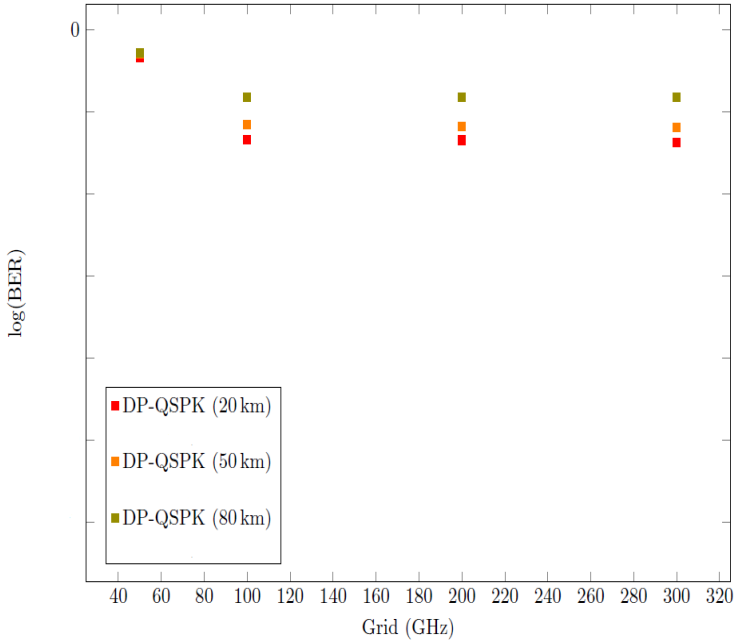
- The main purpose of this scheme is to evaluate the ITU Grid with coherent and simple On-Off Keying system (represents as precise time transmission).
- Simulation topology: White Rabbit (1.25 Gbps OnOffKeying signal) and 100G DP-QPSK.
- We did the simulations for 50, 100, 200, and 300 GHz channel spacing with Bit Error Rate (BER) observing of each system.
- **Launched** power 0 dBm for both signals.
- VPIphotonics Transmission Maker tool was used.
- Simulations done by Tomas Horvath (WP7 member).

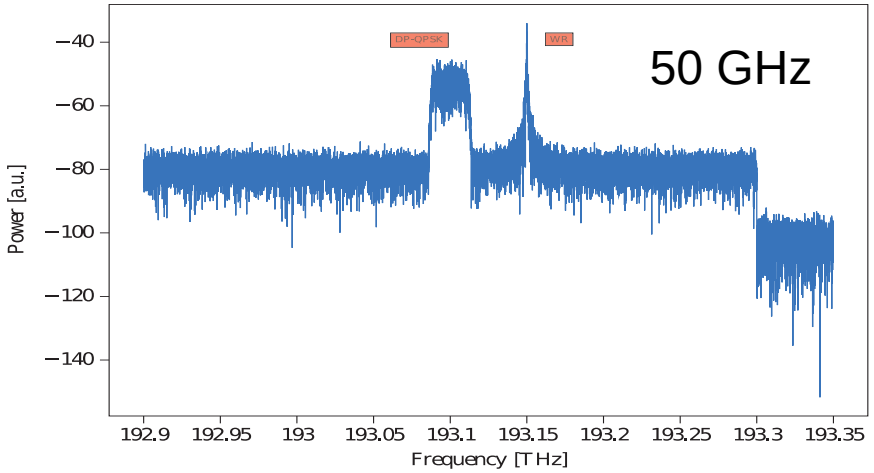
Simulation Topology



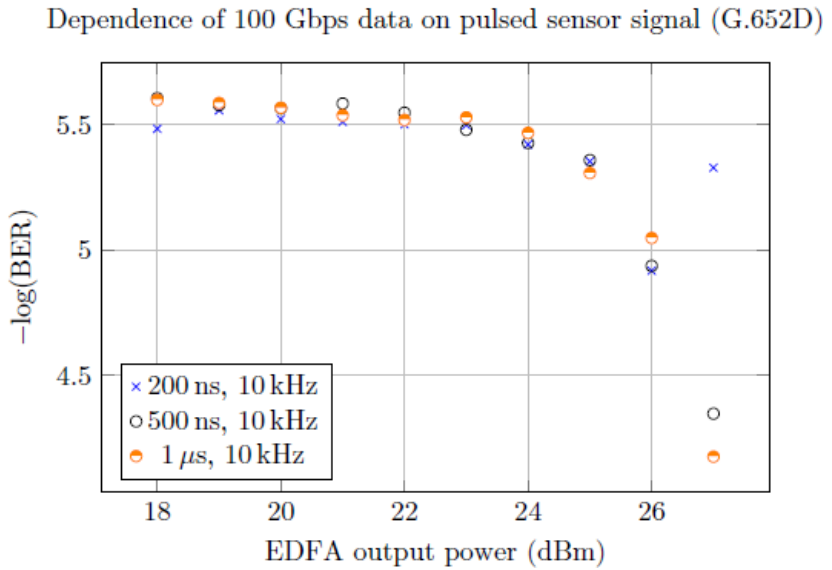
Simulation Results

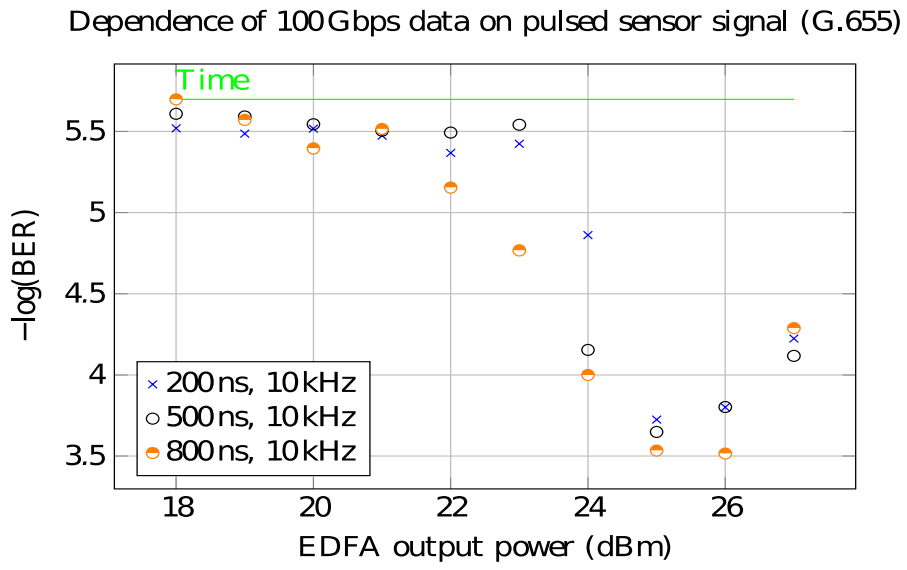
- Influence becomes marginal over 100GHz
- The simulation results show that the worst BER was reached with 50 GHz channel spacing.





- **Parallel operation of phase sensitive OTDR with coherent data**





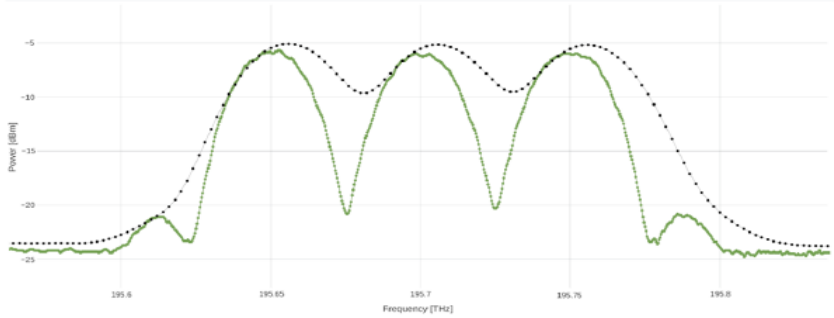
[1] T. Horvath et al.,"Simultaneous transmission of accurate time, stable frequency, data, and sensor system over one fibre with ITU 100GHz grid" Optical Fibre Technology, 2018

Observations

- Real network, 300km, 3 ILAs, mixture of G.655 and G.652 (last miles only)
- Moving 100Gbps channel 100 GHz apart to WR signals, originally was 350 GHz
- One order drop in pre FEC BER, from 2E-9to 3E-8

Open Line System - Czech Light

- When detailed spectrum is necessarry
- Remotelly configurable
  - NETCONF
  - RESTCONF + YANG - push telemetry
- Remotelly monitorable
  - OpenMetrics (Prometheus)
  - Grafana
  - Down to 300 MHz optical resolution
- Chatty ROADMs: Streaming Telemetry with Open Source Software and Open Hardware (ECOC 2021)
- https://www.youtube.com/watch?v=zPdA_GX4rPI0



Conclusions - Lessons Learned

- Parallel operation in long term routine operation
- Trade off between preFEC BER and guard band between coherent and WR signals

- Recommendations
  - Guard-bands between WR and coherents channels large enough
  - In case of insufficient bandwidth, short channels will perform OK close to WRs

Thank You Very Much for Kind Attention!

Questions Please?

josef.vojtech@cesnet.cz