NGN Workshop

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Research networking using programmable photonic devices

Stanislav Šíma, Jan Radil

Authors participate on Optical networks activity of CESNET research program, GN2 project and Phosphorus project

Presented ideas do not necessarily reflect an official opinion of CESNET or any other institution or project.

New possibilities of research networking

- Transfer from telco services to dark fibre usage is widely accepted
- CBF trials have been successful
- Lit fibre service trial has been successful
- Fibre lighting, wave switching and splitting is available using programmable photonic devices, enabling quick trials and deployment of new network features and services
- Turning of photonic industry advances into new network equipment and network services is accelerated

Dark fibres for RENs in Europe

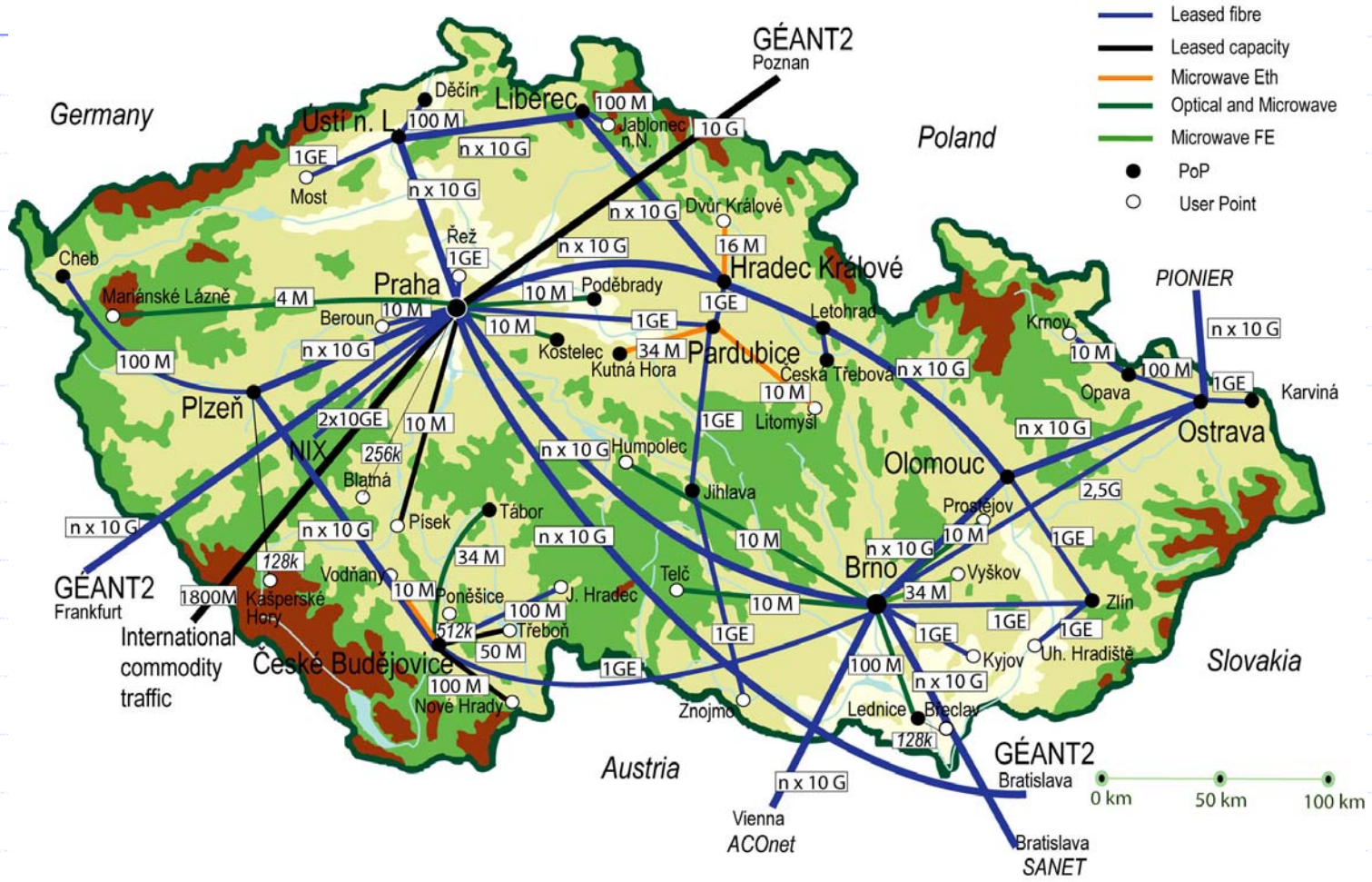
Transfer of research results into new products and services

- Turning knowledge into new products and services is strongly requested in many countries and EU
- For example, the UK e-Science Programme: The Government's vision is that the UK should be one of the most attractive locations in the world for science and innovation, being a key knowledge hub in the global economy, with a reputation not only for outstanding scientific and technical discovery, but also a world leader at turning that knowledge into new products and services. This ultimately delivers benefits for the UK in terms of new goods and services and other less direct benefits in terms of better healthcare, better public services, policy making and cultural benefit.
- In the Czech Republic, reviewers of our research program are strongly requesting to continue with transfer of research results into products and services. Situation of other NRENs is mostly similar …..

Transfer of research results by means of RENs is very quick and effective

- Usage of global Experimental Facilities such as GLIF, GN2 testbed, CESNET Experimental Facility and others
- Usage of in-service research networks such as CESNET2 a GÉANT2
- Transfer of research results to facility users and to network users (for example EDUROAM, collaborative environment, ...)

CESNET2 Topology (October 2007)



Programmable photonic devices

- Photonics industry products readily available in the market and based on standards allow building of fully programmable optical network platforms.
- That extends well-known open approach from software development to hardware and optical devices development and management.
- For example, the CzechLight (CL) family is affordable set of photonic devices enabling to use full advantage of up-to-date products of photonic industry
- Availability of transmission parameters to monitoring and management (impairment monitoring and lightpath switching and restoration, testing of reconfigurable optical transport systems, etc.)
- Fully open to improvements during network life cycle

CzechLight family and layer question

- CzechLight (CL) family:
  - CLA: family of EDFA amplifiers
  - CLR: Raman amplifier,
  - CLS: Optical switch,
  - CLC: tuneable CD compensator,
  - CLM: multicast switch
  - next CL devices are prepared
- Concept was proved by deployment in fibre reels, CESNET Experimental Facility (field fibres) and CESNET2 network (in-service), devices are very reliable
- Interesting question:
  - are CLS and CLM low layer networking equipment?

  (what is more relevant: their function or their pure optical implementation?)
- what about possible pure optical implementation of other functions?

Main types and indicative prices of CLA

- Main types without gain flattening for up to 8 channels:
  - CLA PB01 (8900 EUR) Low noise preamplifier and booster amplifier with output power up to 20dBm and optional ALS (Automatic Laser Shutdown)
  - CLA PB02 (12950 EUR) Low noise preamplifier and high-power booster amplifier with output power up to 27dBm and built-in ALS
  - CLA DI01 (8300 EUR) Dual in-line amplifier with output powers up to 15dBm
- Main types with gain flattening for up to 32 channels:
  - CLA PB01F (10870 EUR) Gain flattened low noise preamplifier and booster amplifier with output power up to 20dBm and optional ALS
  - CLA PB02F (14980 EUR) Gain flattened low noise preamplifier and high-power booster amplifier with output power up to 27dBm and built-in ALS
  - CLA DI01F (9350 EUR) Gain flattened dual in-line amplifier with output powers up to 15 dBm

Prices for 1-2 pc in September 2007

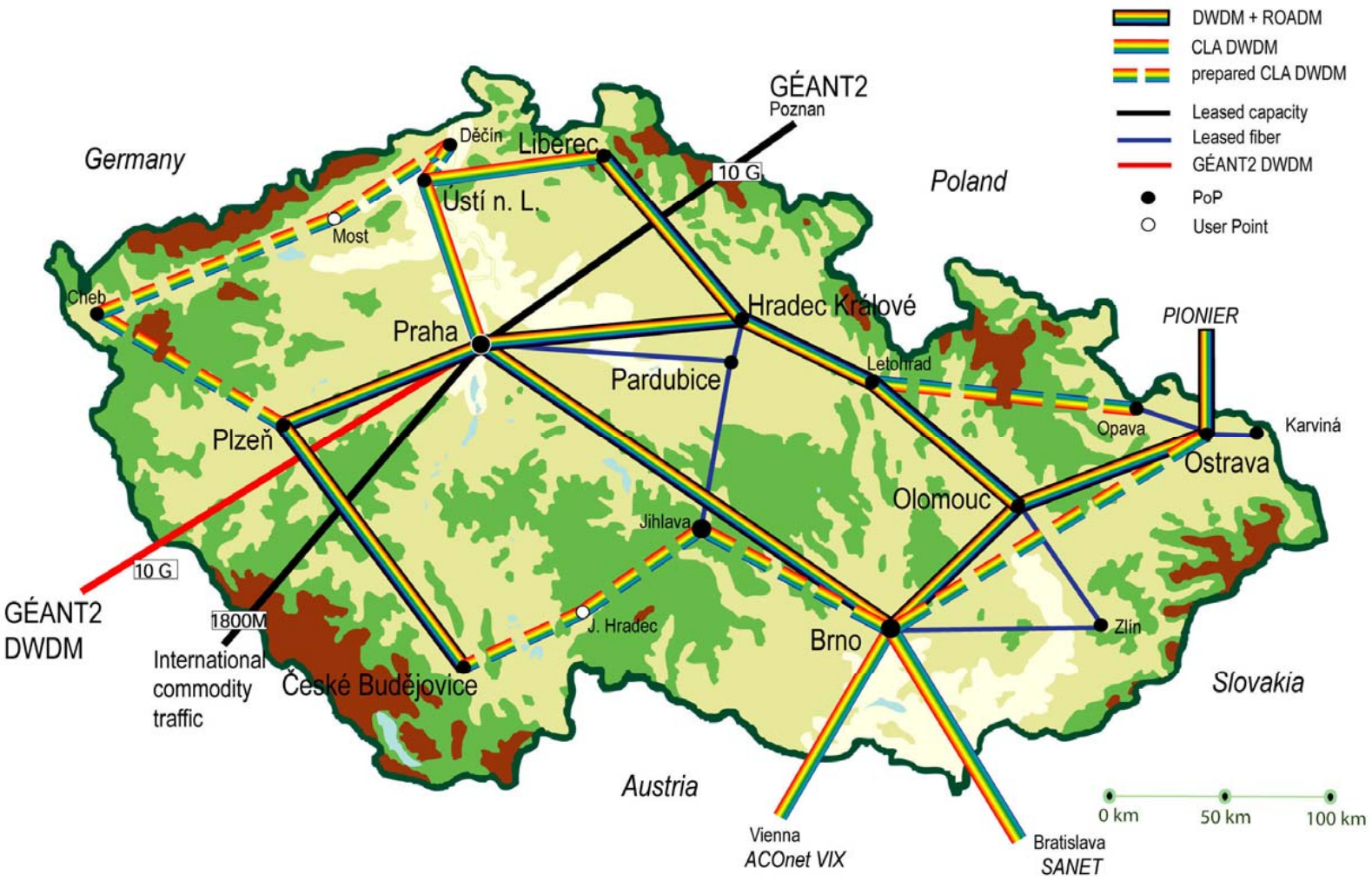
Fibre network cost model

- General cost model was elaborated in Porta Optica Study (POS), FP6 SSA project http://www.porta-optica.org/
- Model is based on annualized network costs
- The most important task of REN from economical point of view is usually to overcome distances
- Corresponding cost category is transmission cost as sum of
  - fibre usage cost and
  - fibre lighting costs
- Transmission costs are usually about **80 %** of costs of operation (fibre usage costs about 55% and fibre lighting costs about 25%).
- **Model allows comparison of different solutions**
- See POS Deliverable D3.2: „Economic analysis, dark fibre usage cost model and model of operations"

Licensing and deployment

- CLA: non-exclusive licence and know-how contracts with two vendors, open to other vendors
- Deployment of 4 pcs CLA on Experimental lines is ready (started 2004)
- Deployment of 16 pcs CLA in CESNET2 is ready (started 2005)
- Including deployment in Bratislava (Slovakia), Vienna (Austria) and Cieszyn (Poland)
- Further deployments in 2007: 32 pcs of CLAs in summary
  - Including 4 DWDM 10G lines in CESNET2 and 2 DWDM 10G lines in experimental lines
- Better service to Aconet, CESNET2, Pionier and SANET users: no such 10G and DWDM lines would be possible without CLA (for cost reasons and fixed budget)
- Enabling GLIF demo: One Side Amplification (OSA) by CLA for DWDM over CWDM (lambdas Zikova – Celetna in Prague)
- We search partners for deployment in NRENs

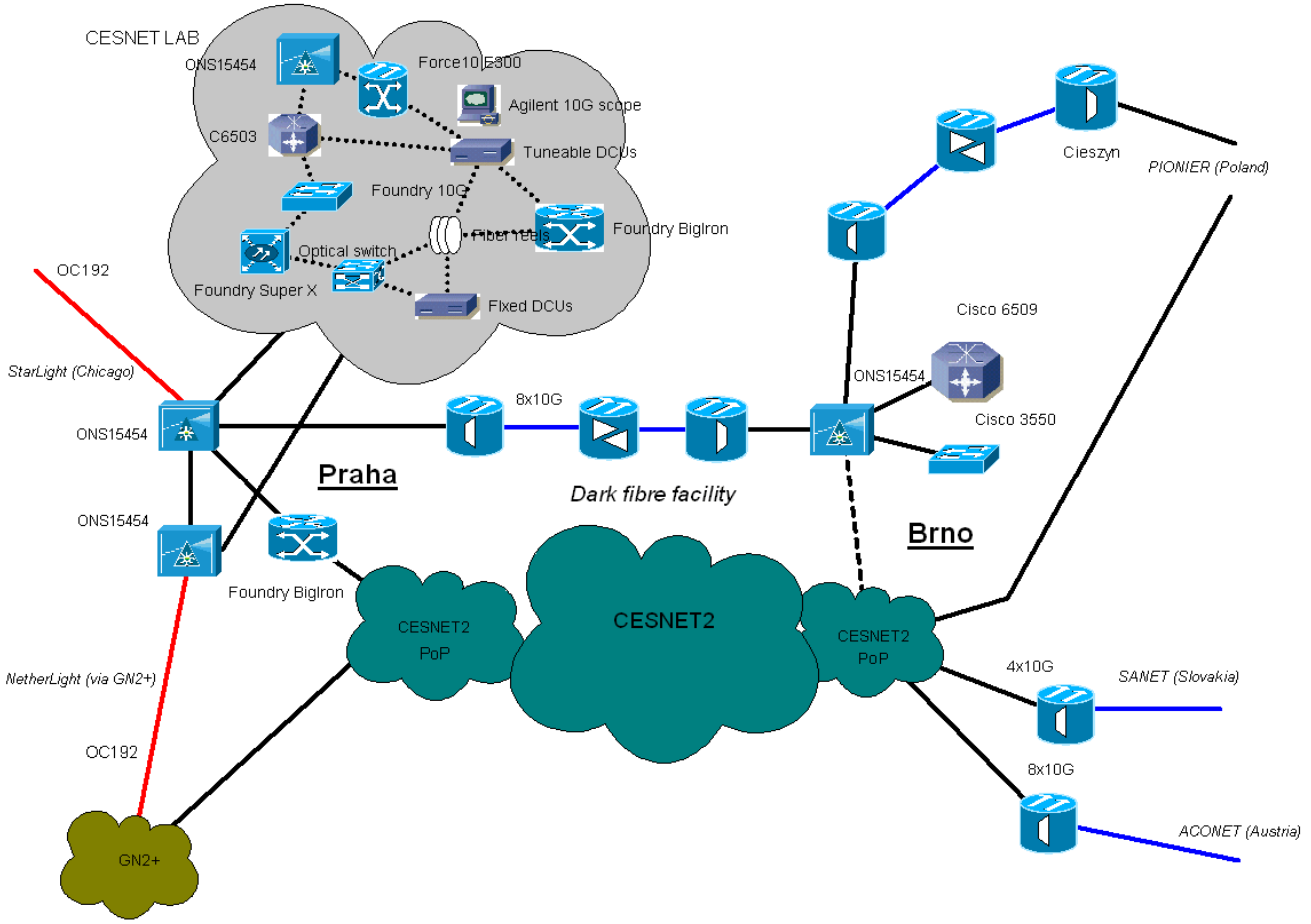
CESNET2 DWDM lines operated and prepared in 2007



Dark Fibre and Photonics Experimental Facilities

- Experimental Facilities including dark fibres are needed for transfer of research results to network equipment and services
- Open dark fibre and photonic Experimental Facility (EF) should be dedicated for support of designing the Internet of the future at all network levels (from dark fibre lighting to network applications in different research areas).
- We distinguish between EF and testbeds (EF is multi-purpose, long term and less technology/vendor dependent)
- EF enables advances in network development by supporting experiments and applications
- EF needs users: instead of service delivery to users, research collaboration on experiments is the goal

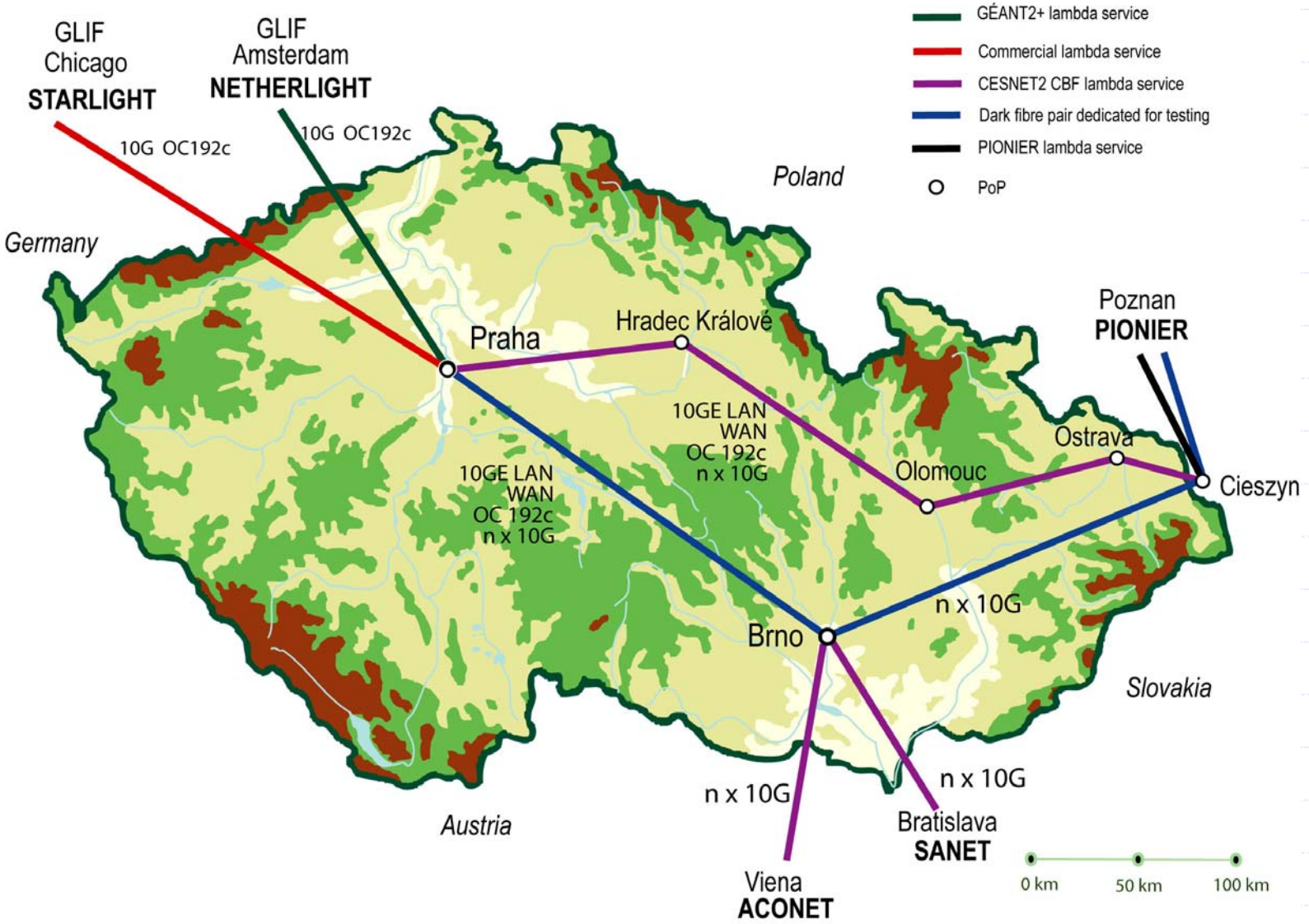
CESNET Experimental Facility, October 07



CESNET EF

- CESNET Experimental Facility (EF) consists of dark fibres, CLAs and switches
- EF is used for
  - testing of new CL devices and new photonic products,
  - for bulding and operation of testbeds (now Phosphorus testbed),
  - disruptive experiments with new services and products before deployment in CESNET2, CBF, etc.
  - support of experiments with new applications and research collaboration
  - first mile solutions testing
- EF users: we collaborate with GLIF users in the Czech Republic – collaboration of facilities users looks very reasonable
- We are searching for international partners and projects with similar approach

Phosphorus Testbed Topology in CZ (October 2007)



What is done – optical amplifiers

- Optical amplifiers
  - EDFAs
    - boosters, preamps, inlines, 2in1
  - Raman
    - amplification only – extending reach
    - TDM pumped Ramans to suppress transient effects in long haul DWDM networks
- Deployment since May 2004 (non CLA optical amplifiers deployed since 2002)

What is done – optical amplifiers

- The CLA EDFA includes 2 in 1 Single Channel Pre Amp and Booster EDFA. The electronic control board permits to control separately the 2 EDFAs. Different control modes are available AGC (automatic gain control), APC (automatic power control), ACC (automatic current control) on each stage.
- Features
  - Low noise figure
  - Wide wavelength range
  - Low power consumption
  - Microcomputer control system
  - RS232 , Ethernet, USB interfaces
  - Multi channel amplification (e.g. long-haul DWDM)
  - Single channel amplification (e.g. CATV)
  - Booster / In-line / Preamp

What is done – optical amplifiers

- Dimensions
  - Standard 1U rack case size 19" (W) x 19" (D) x 1.75" (H)
  - Shallow 2U rack case available
- Up to 4 EDFAs (customer based) in one rack case
- Dual PSUs for redundancy
  - (100-230 V AC or 48 V DC each up to 150 W, typical consumption 50 W)
- Management based on Linux
- Possible interfaces
  - Wired: RS-232, Ethernet, USB
  - Wireless: GSM/GPRS/UMTS, Wi-Fi, BlueTooth

What is done – optical amplifiers

- Tools
  - CLI via ssh, SNMP
  - Critical warnings are sent via e-mail, SNMP Traps
  - Net-SNMP package - for future development
- All important parameters are monitored (output powers, alarms, laser diode currents, temperatures, voltages, fan speeds,...)
- Booster, inline and preamplifiers
  - EDFA modules may be selected to best fit your applications
- Without gain flattening for small channels count (up to 8 DWDM channels)
- With gain flattening for up to 32 channels (or more)

What is done – optical amplifiers

- APR (Automatic Power Reduction) - for high power units only
- Management and monitoring - in addition CLAs can monitore PSU voltages and temperatures, fan speeds, case temperature(s)
- LCD display for alarms and management parameters - optional
- What additional features?
  - Linux is used as an operational system so CLAs can be used to test connectivity with ping, traceroute etc.

New equipment

- Based on the CLA design
  - Seems to be a good idea and decision
  - ‚A new peripheral device only‘
  - Modular, management capabilities, upgrades, redundant
- Important for higher speeds and lightpaths

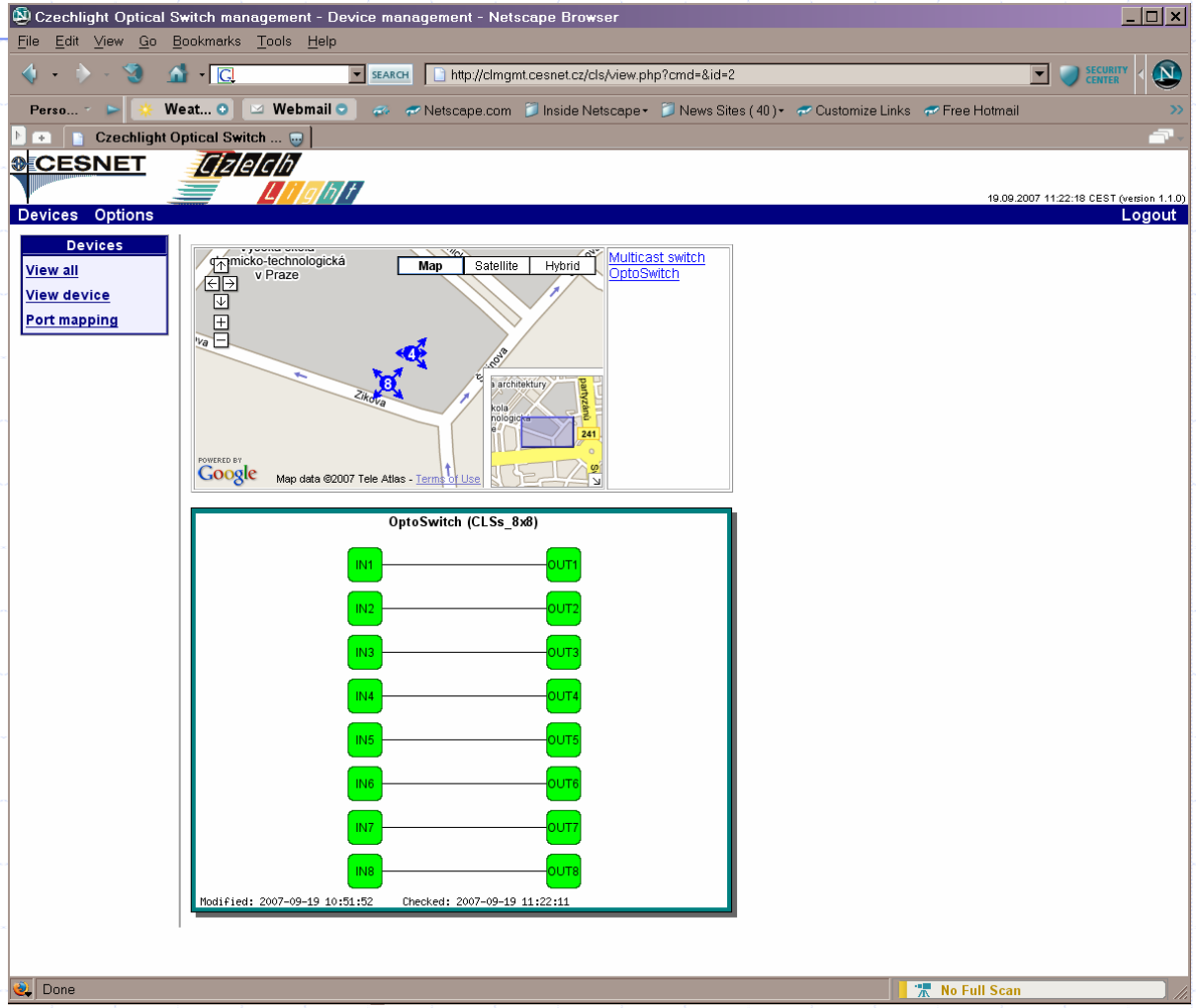
New equipment

- Tuneable compensators of chromatic dispersion
  - Not only FBG but Gires-Tournois etalons
  - FBG for speeds above 10 Gb/s
  - Up to 160 Gb/s optical signals
- Optical crossconnects or switches
  - Clever patchpannels
    - 8 x 8 matrix (1 to 1)
  - With additional features
    - multicasting (1 to many)
- Wavelength convertors and 2R regenerators
  - SOA based

New equipment – Optical crossconnect

- 8 x 8 switching matrix (from a commercial vendor)
  - Pretty raw, some interface for NOC folks really needed
- Again, the basic idea from the CLA design
- Web based management - GUI
  - User accounts with different privileges (configure/check)
  - AAA if needed, LDAP
  - Time scheduler for sharing of expensive resources
    - International links (lambdas)
    - Power PCs
    - ‚I would like to get a 10G link from 2 a.m. to 6 a.m. for my experiments‘
    - Perhaps the most important thing

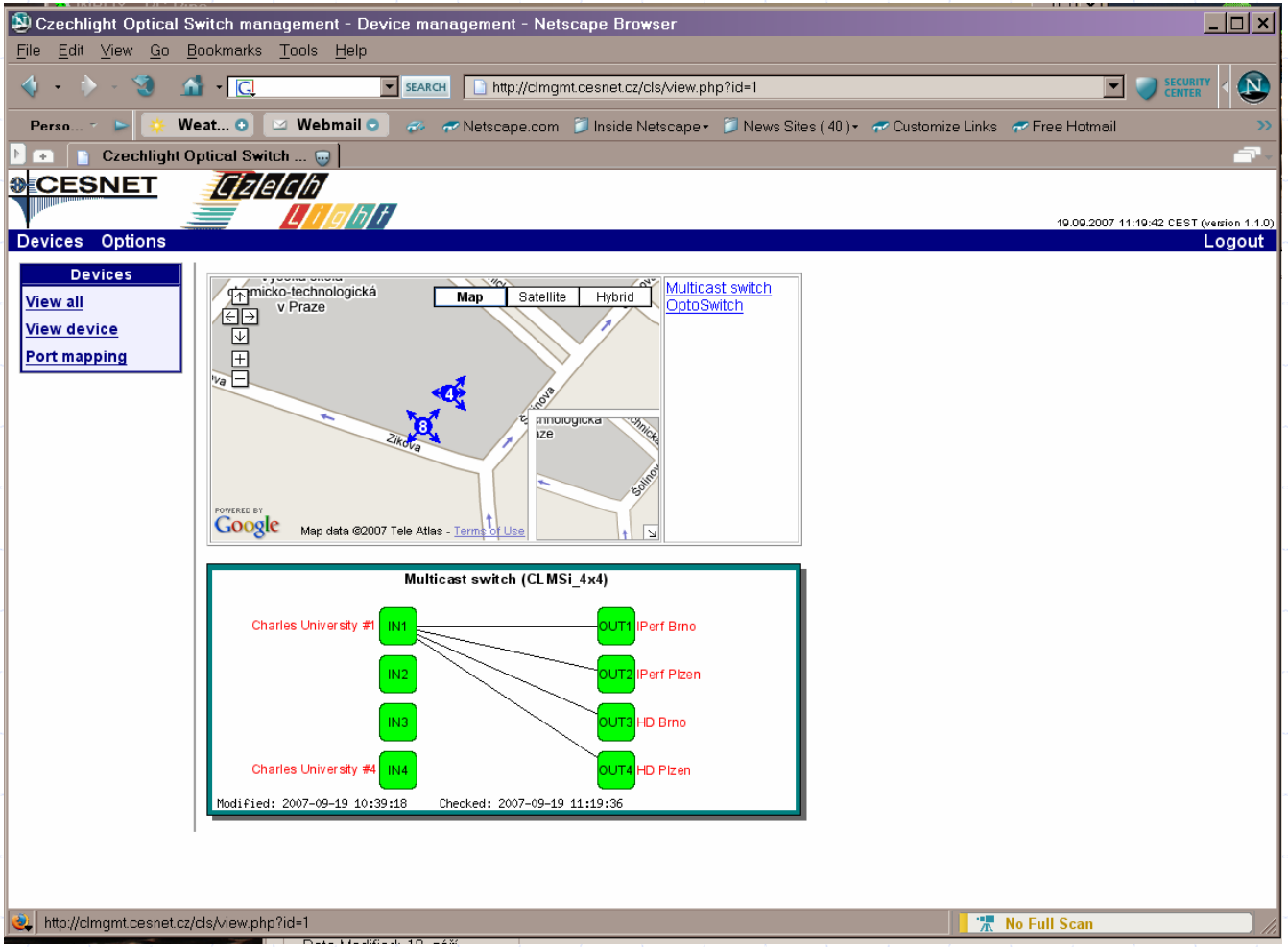
New equipment – Optical crossconnect



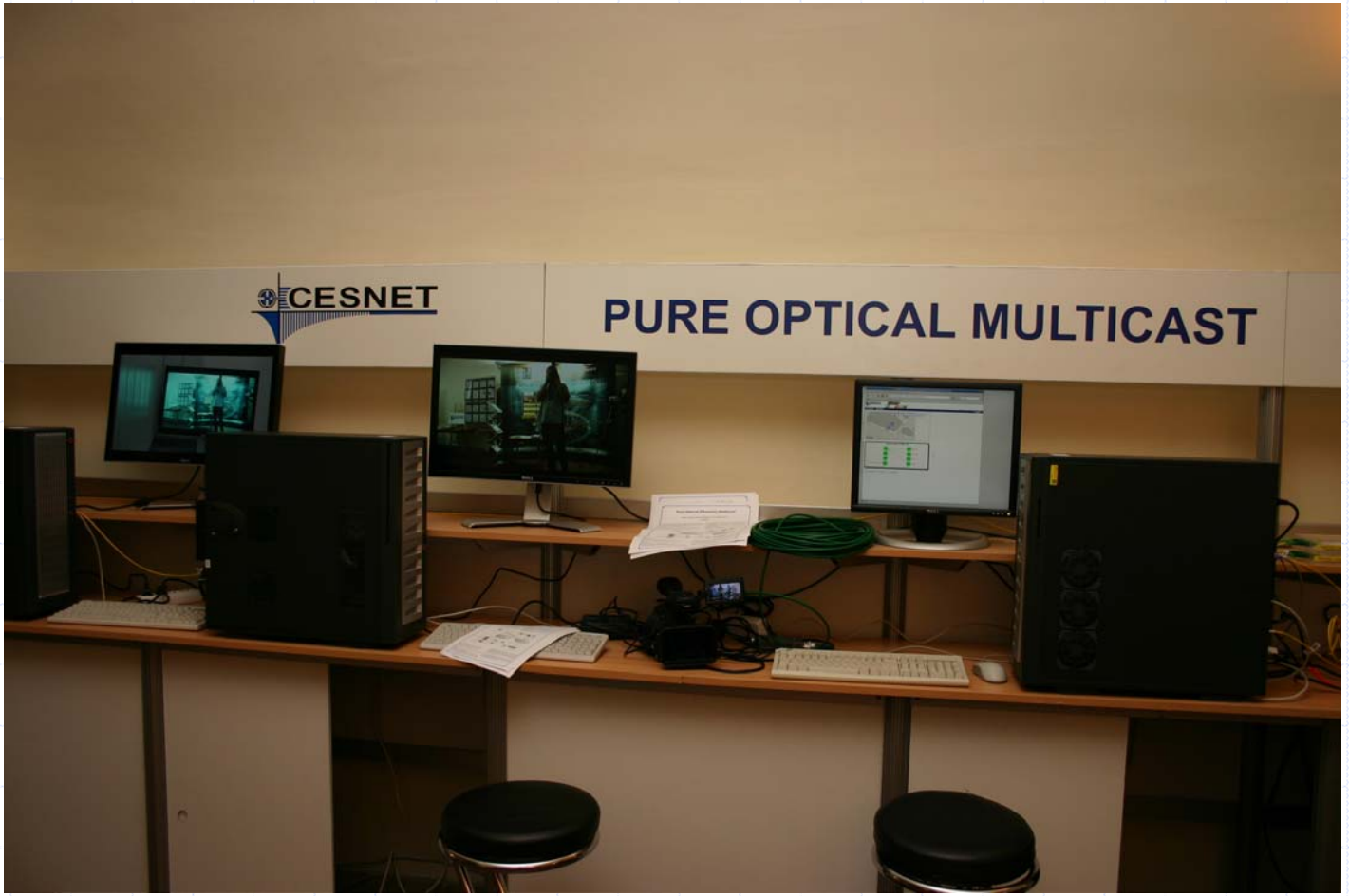
New equipment – Optical multicast

- Different requests
  - GUI useful and perhaps needed
- True optical multicast, not SONET/SDH drop and continue or port mirroring known from routers/switches
  - Protocol agnostic, 1 to many (limited by optical losses but can be compensated for by amplifiers)
  - Allows combinations of switching and multicasting from 1:1 to 1:4
- Again, the basic idea from the CLA design
- Web based management
  - User accounts with different privileges (configure/check)
  - AAA if needed, LDAP
  - Time scheduler for sharing of expensive resources

New equipment – Optical multicast



New equipment – Optical multicast



Optical/photonic unicast/multicast switches/crossconnects

- ...currently-evolving lower-layer issues...
- Is it Layer 0 or 1 or 2?
  - Layer 0 not a part of the ISO/OSI reference model
  - Terms are misused (casually or intentionally)
  - Eg. in SDH/SONET, circuits are „routed" but without routers
- Switch or crossconnects?
  - Switch can read information from data
  - Crossconnect does not understand signals
- „A 3D-MEMS crossconnect switch with 220 ports"

Optical/photonic unicast/multicast switches/crossconnects

- Optical
  - Optics (ὀπτική appearance or look in Ancient Greek) is a branch of physics that describes the behavior and properties of light and the interaction of light with matter. Optics explains optical phenomena.
- Photonic
  - Photonics is closely related to optics. However optics preceded the discovery that light is quantized.
  - Photonics is approximately synonymous with quantum optics, quantum electronics, electro-optics, and optoelectronics. However each is used with slightly different connotations by scientific and government communities and in the marketplace.
- From wikipedia.org

Optical/photonic unicast/multicast switches/crossconnects

- Rather crossconnects
- Perhaps it is not necessary to ‚squeeze' new equipment into L0/1/2 categories?

New equipment – Conversions/Regenerations

- Based on SOAs
  - Can be done with HNLF but high optical powers necessary
- 10 Gb/s, tested up to 40 Gb/s RZ signals
- Tested in our lab, more difficult to make a ‚black box' ready for deployment (polarization sensitive, more control elements)

Conclusions

- Experience: these innovative optical/photonics devices must be ready for deployment, in other words NOC folks should find most of ‚standard' features
- New features and possibilities, not economic reasons only
- Experimental facilities (with dark fibres) are important
- If anybody is interested please let us know
- What should be dark fibre EF in GN3?

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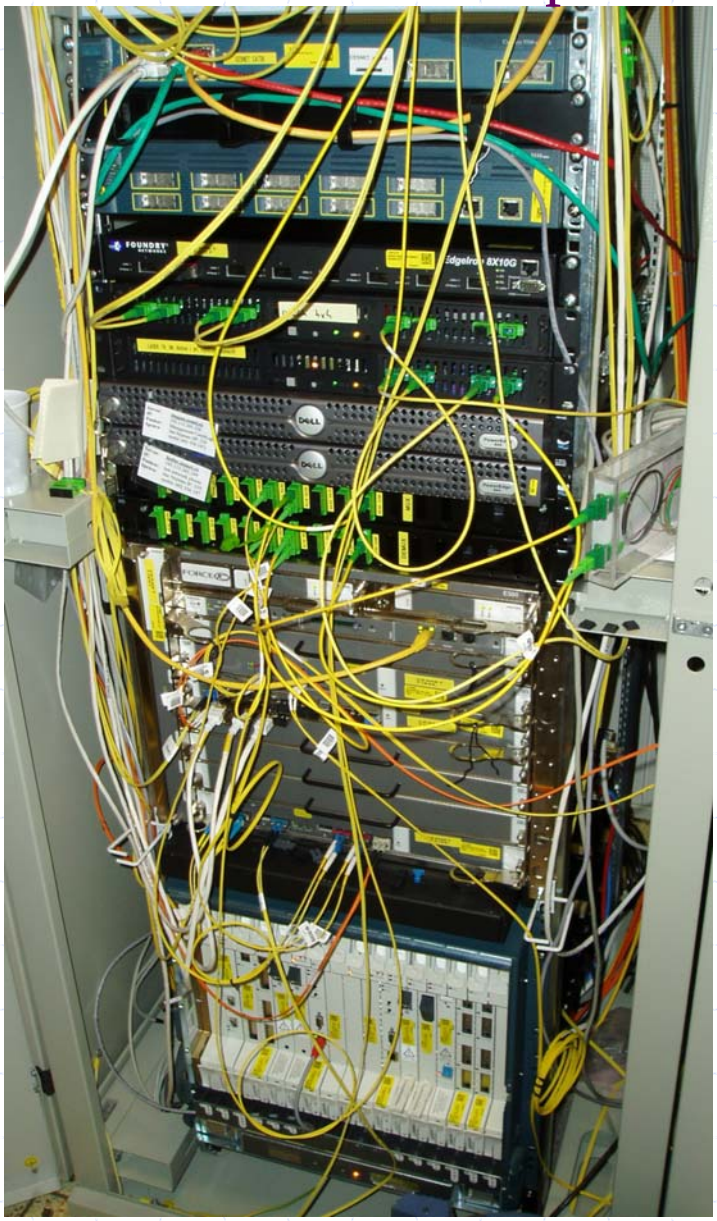
Acknowledgement

- All partners from CEF Networks community, especially Jan Gruntorád and colleagues Lada Altmannová, Miloslav Hůla, Miroslav Karásek, Jan Nejman, Martin Míchal, Václav Novák and Josef Vojtěch from CESNET

Above colleagues are not responsible for any our mistake ☺.

Q & A



Thank you for your attention!