Customer Empowered Fibre Networks Research and Experimentation

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Author participates on:

CESNET research program (www.ces.net),

GN2/3 project (www.geant.net),

Phosphorus project (www.ist-phosphorus.eu/about.php)

Presented content do not necessarily reflect an official opinion of any institution or project.

Optical High Speed National Research Network and its New Applications

- Research plan 2004 – 2010, funded by Ministry of Education, Youth and Sports of the Czech republic and 26 association members
- Budged cca 14 mil. EUR/year
- Research Activities about CEF (2 of 10):
  - CESNET2 backbone network development – Václav Novák
  - Optical networks – Stanislav Šíma
- Research Activities annual reports available

http://www.cesnet.cz/doc/2008/networking-studies/

- ***Fast verification and deployment of research results in networks was achieved***

Why is fast transfer of research results to networks difficult

- Multidomain and multivendor scenario of Internet services, dependency on vendors
- Technology road maps of telco operators and equipment vendors is oriented to Return of Investment and saving business continuity
- Most of telecommunication services, transmission and switching systems used in telecommunication networks have not detailed specifications of all layers available to the user, user is not allowed to do modification
- Implementation of management of advanced services for Research and Education Community (for example e2e lightpaths) depends on
  - Coordinated manpower needed in GÉANT, NRENs, Metropolitan and local networks
  - Changes in data link layer and physical layer depends on vendors participation
- ***Right motivation of vendors by Public Private Partnership (PPP) is not yet sufficiently prepared***

Open scenario needed

- Open scenario is inevitable for fast transfer of research results to networks (fast innovation)
- Open scenario is in principle vendor independent:
  - Multivendor domains (mixed architecture) are supposed in general
  - Services or equipment are acceptable if interoperability is guaranteed
  - Extension or change of equipment or service types on demand is fast
- CEF Networks: full access to dark fibres gives independency on telco services
- Open transmission systems give independency on vendors of „equipment or services with hidden layers"
- Open scenario use telco services or equipment with hidden layers, if competitive
- *Open scenario with full access to dark fibres and open transmission systems are inevitable for research of networking, clean slate approach, Future Internet research and experimentation etc.*
- Research and Education Community especially needs freedom in communication in above sense

Vendor-independent integrator for open scenario

- Transmission system design and testing in single-vendor cases is usually done by the transmission system vendor (not by the NREN or Users)
- In multi-vendor or multi-domain cases, it is probably more appropriate to use service of a specialized third party company - vendor-independent integrator.
- Nevertheless, qualified formulation of requirements is needed anyway.
- It should be noted, that research teams in some NRENs have demonstrated the capability to do the integrator task and to help others.

Fast transfer of research results

- Crucial points for fast transfer of Research results (fast innovations):
  - Research driven by Experiments
  - Equipment prototyping
  - Motivation of users, for example energy savings, space savings, long reach and higher speed by photonic (all-optical) transmission
  - Dark fibre, physical layer and data link layer availability to network designers
  - Testing in dark fibre Experimental Facility
  - Licensing of production
  - Deployment in NREN, evaluation by NREN users
  - Deployment by ISPs or FTTx vendor
- Many possibilities to enhance applications can be find in physical layer
- In many cases we can gauge before network users, what new physical layer possibilities will bring improvements in future
- In Research and Development driven by experiments, it is important to verify and evaluate real possibilities, create new offer of services for users, and find early adopters

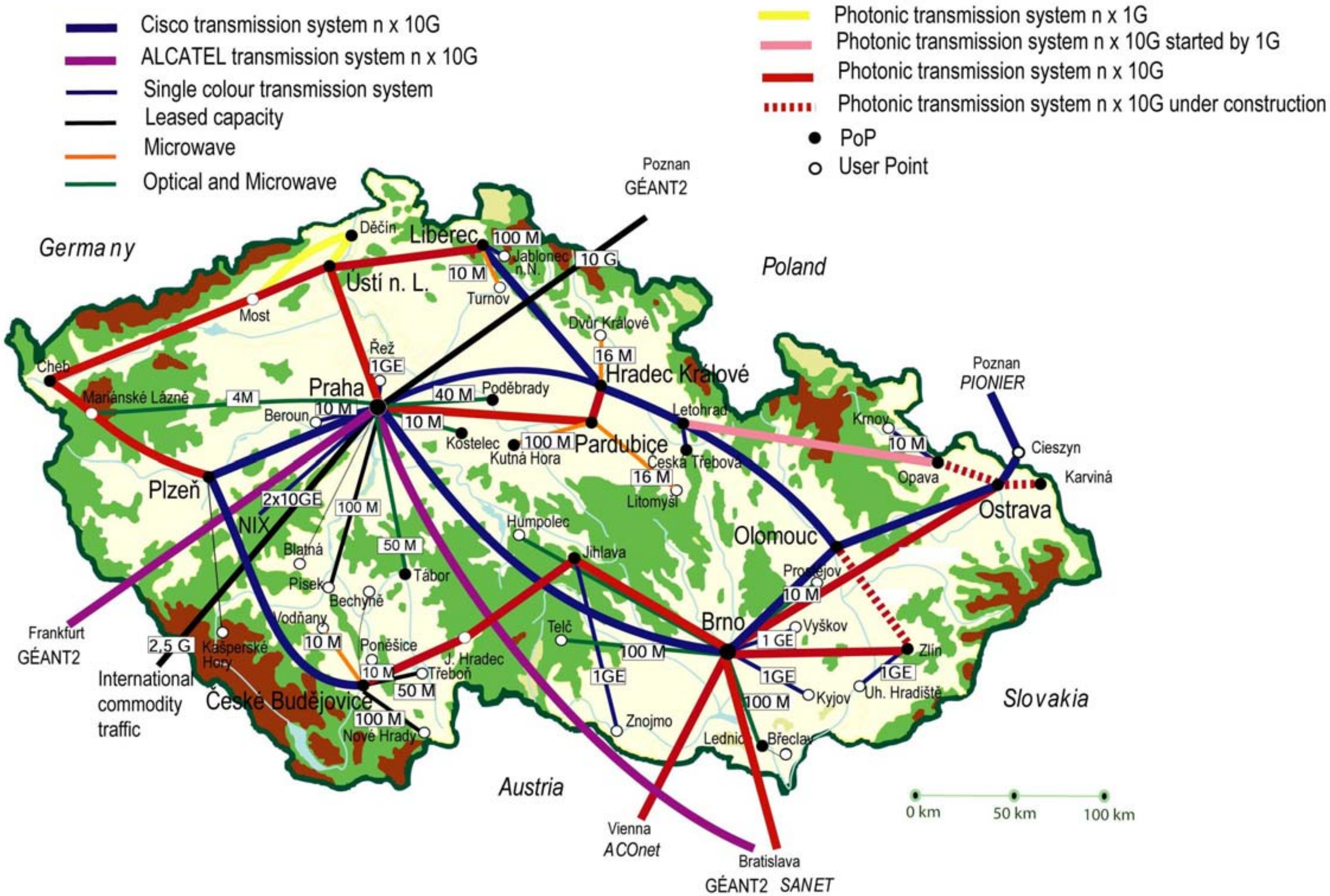
New concepts developed and deployed in CESNET during research plan

- CEF (Customer Empowered Fibre networks)
- NIL (Nothing In Line)
- CBF (Cross Border Fibre)
- Dark fibre Experimental Facility
- Open DWDM transmission systems and network devices (all layers available):
  - Enabling to use new advanced components from photonic industry: Long reach, high speed, energy saving
  - Advanced remote technical support – see presentation of Jan Radil
  - Deployed by 5 ISPs – see presentation of Lada Altmannova
- Single fibre bidirectional Open DWDM transmission
- ***Open scenario in network architecture*** – proved interoperability of open and other DWDM system on physical layer: multivendor support for single domain (good also for interconnections of domains)
- ***LTTx:*** Lightpaths to the x (to dispersed end users and applications) http://www.glif.is/meetings/2008/rap/sima-lttx.pdf

Open scenario: open source software design principles applied to the physical layer of networks

- Concept of utilising Open DWDM systems and design principles can be likened to open source software design principles being applied to the physical layer of networks.
- This is the antithesis of so-called "closed systems" in which all the components of a transmission system are integrated and sold as a turn-key solution by a single vendor.
- In closed systems there is usually little room for cross-vendor integration at the optical layer (if not always because of real physical incompatibilities, this can often be attributed to limitations imposed by the conditions of warranties or maintenance agreements).

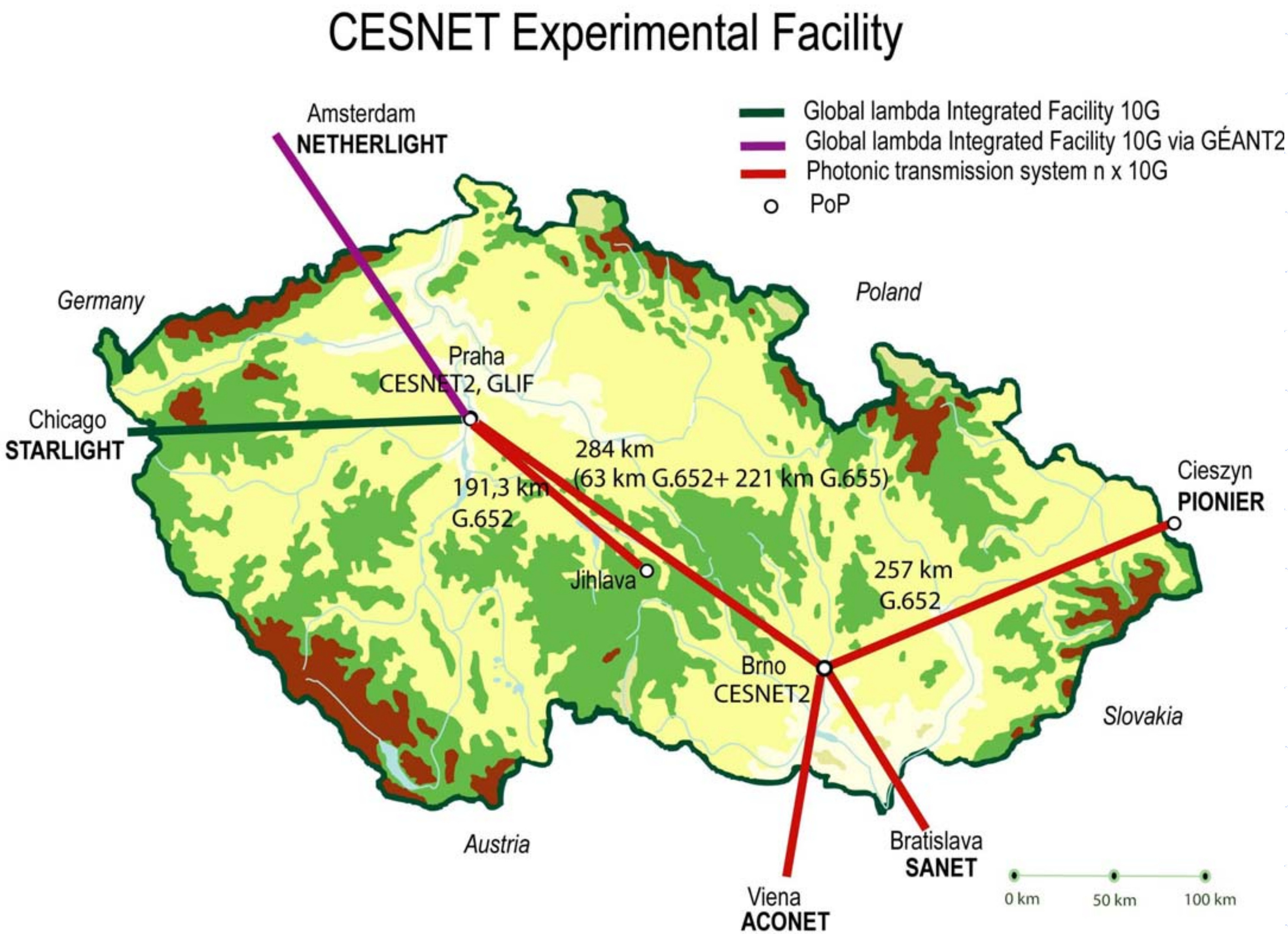
Multivendor network with all-optical e2e lambdas



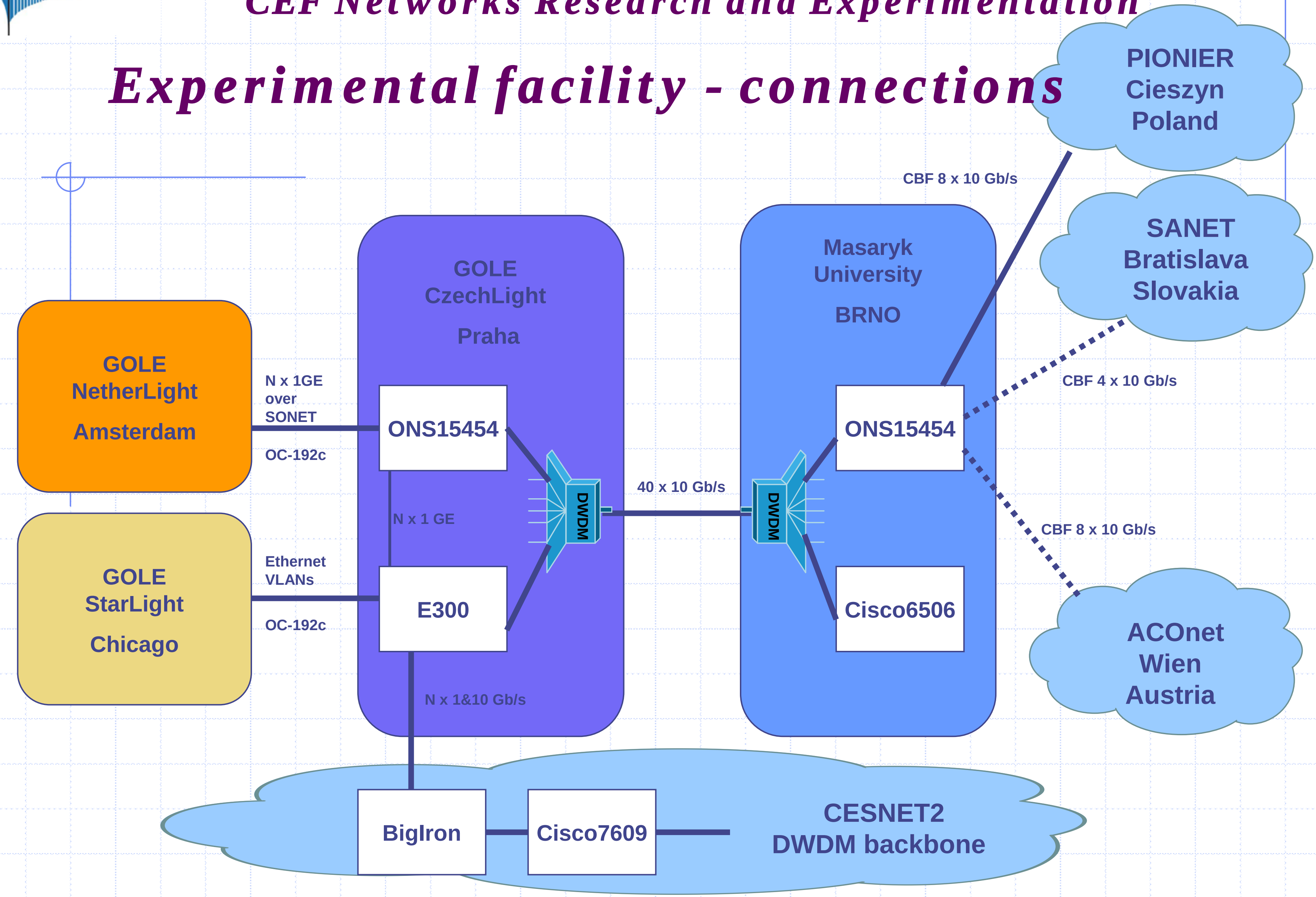
More details are available in presentations of my colleagues from CESNET

New concepts in development

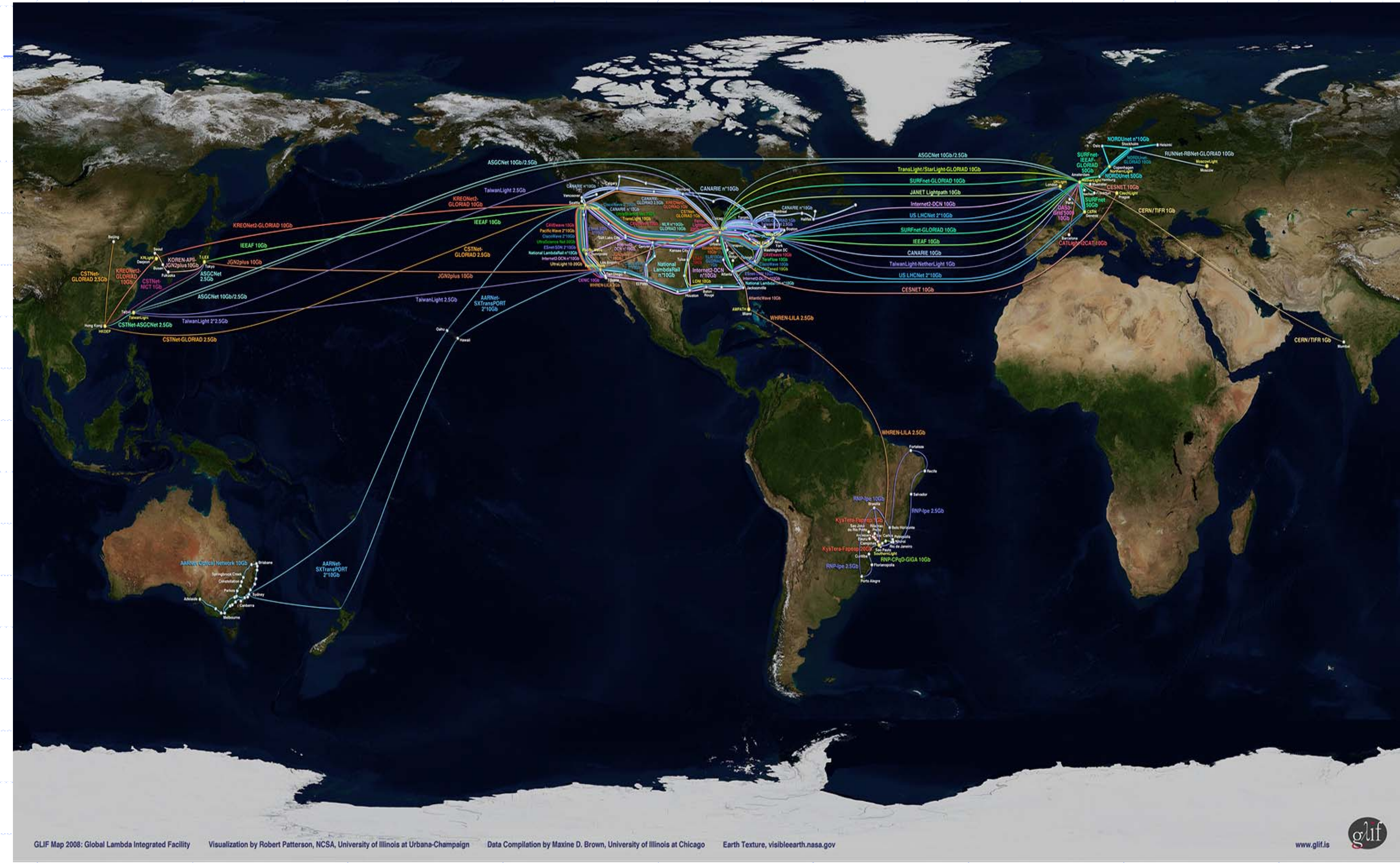
- Dark fibre EF federation
  - The development and interconnection (federalization) of experimental facilities (open multi-purpose test-beds) enabling field technology testing and user participation should be supported
  - Give researchers an experimental environment for validating innovative – and potentially disruptive – architectures and technologies including physical layer. Many issues are only discovered when technology, devices or systems are deployed in "real-life" situations.
- Remote setup, restoration and maintenance of open devices
- Tools for design of photonic networks, Network Aided Network Design (NAND)
- Conceptualization for photonic networks design


CESNET Experimental Facility
Global lambda Integrated Facility 10G
Global lambda Integrated Facility 10G via GÉANT2
Photonic transmission system n x 10G
PoP
Amsterdam
NETHERLIGHT
Germany
Poland
Praha
CESNET2, GLIF
Chicago
STARLIGHT
284 km
(63 km G.652+ 221 km G.655)
191,3 km
G.652
Jihlava
257 km
G.652
Cieszyn
PIONIER
Brno
CESNET2
Slovakia
Austria
Bratislava
SANET
Viena
ACONET
0 km
50 km
100 km

Experimental facility - connections

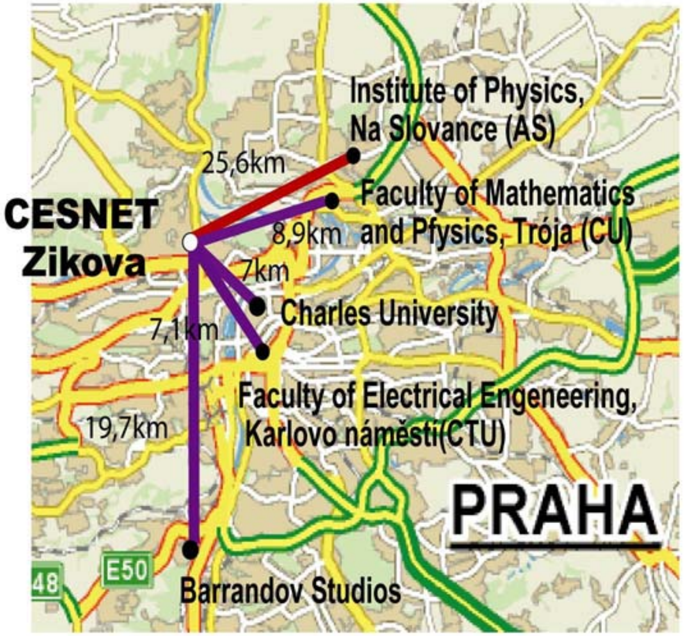


GLIF


GLIF Map 2008: Global Lambda Integrated Facility
Visualization by Robert Patterson, NCSA, University of Illinois at Urbana-Champaign
Data Compilation by Maxine D. Brown, University of Illinois at Chicago
Earth Texture, visibleearth.nasa.gov
www.glif.is

LTTX: from GOLE to dispersed users

Metropolitan DWDM for e2e connections



- Photonic transmission system n x 10G
- Dark fibre prepared for n x 10G

AS	The Academy of Sciences of the Czech Republic
CU	Charles University, Praha
CTU	Czech Technical University, Praha

Towards machine aided tools for design and maintenance of photonic networks

- Work on transmission system designs by using advanced optical amplifiers started in CESNET in 2001. We operated 189 km NIL transmission line Praha-Pardubice since 2002. *We have entered scenario of building NREN transmission system as multivendor domain by this step, i.e. open scenario.*
- We have understand importance of tools supporting transmission line design, testing of abstract transmission line models, specification, documentation, implementation with possibility of remote setup and maintenance including machine aided recovery.
- Based on development of CLS, CLM and other advanced photonic devices, we should speak about design, modeling, testing, specification, documentation and maintenance of photonic networks instead of transmission lines only.
- Having experience with electric circuit design tools and computer design tools, we keep in mind that formal syntax and formal semantics of a specification language will be needed for
  - advanced tools allowing composition of specifications
  - testing of consistency between description and real network setup
  - deriving network properties from network specification

Importance of tools for photonic network design

- Importance of photonic (all-optical) transmission and processing in networking is strongly growing. Main drivers are higher freedom of design, higher transmission speed (100Gb/s and more) and saving energy and network maintenance costs (secure economical and "green" advantages).
- Freedom of design and other advantages could be fully exploited, if network aided network design (NAND) tools are available. Similar needs and tools are well understood in electrical circuit design, computer design, database and software design, but looks rather new in network design.
- Development of CAD tools as well as Network Aided Network Design (NAND) tools needs conceptualization and ontology as background for programming of tools. It is more than standardisation and technical documentation, we need:
  - network descriptions suitable for machine analysis and elaboration (formal syntax needed)
  - small *set of network primitives* suitable for describing all-optical networks by combination (semantic definition of formal language needed, at least in natural language)
  - deducing (inferring) or proving of network properties from network description (formal semantics needed)

Conceptualization for photonic network design

- Optical schema was suggested, then expressed in Network Description Language (NDL) and its application is demonstrated in description of Optical Fibre, Optical Transmitter, Optical Receiver and Optical Switch.
- In principle, formal description enables machine processing of some important designer tasks, such as testing or verification of properties of network created by interconnected elements
- Very important task for machine tools is abstraction, i.e. derivation of higher level (simpler) description from lower level (more detailed) description, leaving some (inner) parts or properties of device or network “invisible”.
- In network operation, physical devices should be able to deliver their own NDL description on demand, enabling to update automatically description of network (for example in the case of device upgrade, band allocation or network restructuring).
- We didn’t use NDL during Open DWDM planning yet, but there are some visions for the future. When an optical route is designed and is similar to already designed one, by NDL would be easy to duplicate it and change only required parameters.
- It is considered to be useful to generate automatically NDL description documents from backups of configurations of CL devices, which are saved at the CzechLight server, see real time demo today.
- *Remote collaboration in above work is possible and partners are welcomed.*

Indicators of transmission effectiveness

- Annualised costs of transmission resources are used for cost comparisons
- Transmission resources:
  - Fibres + Transmission equipment + Leased circuits (if network is not fully based on dark fibres)
- Important indicators of transmission effectiveness for given transmission capacity:
  - Transmission cost per year and meter = fibre cost per year and meter + lighting cost per year and meter
  - In-line housing costs should be included in lighting costs (to enable evaluation of hut skipping etc.)
  - For terrestrial leased circuits is usually acceptable to use road distances in calculation
- Transmission effectiveness is the most important item of network effectiveness (transmission costs are usually over 70% of total network costs)

Good Values of Indicators

- Fibre costs per year and km for research networks
  - Equal annual costs supposed (i.e. no installation fee etc.)
  - 100 – 400 €/km/year for fibre pair in „competitive" area
  - up to about 1000 €/km/year for fibre pair in some regions (e.g. rural areas in nearly all countries)
- Sufficient lighting costs per year and km
  - Depends on scenario: example given below for spans from 2x120km up to 4x100km and 4 year life cycle (to allow fast innovation)
  - 135 – 198 €/km/year for 16 x 10Gb/s transmission on fibre pair (including transceivers)
  - 38 – 44 €/km/year for 16 x 10Gb/s transmission on fibre pair (without transceivers)
- ***Indicators for sufficient energy consumption per year and km wanted***

Acknowledgement

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Thank you for your attention!