Photonic network enabling real-time applications

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Innovation and research in optical networking carried out by National Research and Education Networks have opened a new field of advanced applications. The real-time applications can answer to the most demanding requests from research community and make interactive high-definition 3D video transfer or novel precise comparison of atomic clock a reality. Recently conducted real-time applications in purely optical domain of network CESNET2 are presented. This and much more can be provided by proposed purely photonic networks that place reliance in light to carry huge amount of information with precision of laser.

Introduction

The World Wide Web evolution is essentially driven by end-users, who desire new applications to simplify communication, work and everyday life. New applications can even attract communities that were not involved in networking before. Although most sites are connected to the Internet by Internet Service Providers (ISPs), the innovation tasks lay on National Research and Education Networks (NRENs), who manage and operate network for universities and research institutes. It is the ultimate goal that makes the difference in network architectures of NRENs and ISPs. While ISPs pursue maximum capacity to increase profit, NRENs manage their network to support research and allow development of novel applications. Real-time applications open the brand new field of possible applications, but pose high demands on network architecture. Many of these novel applications require a dedicated all-optical channel (all-optical Lambda) that will be established through the network on demand. The most challenging application then even pose limits on network latency in scale of nanoseconds or on timeliness guaranty and availability of network. Although some applications are called on just by highly specialized research centers, there are only NRENs that have the capability to enable such communities.

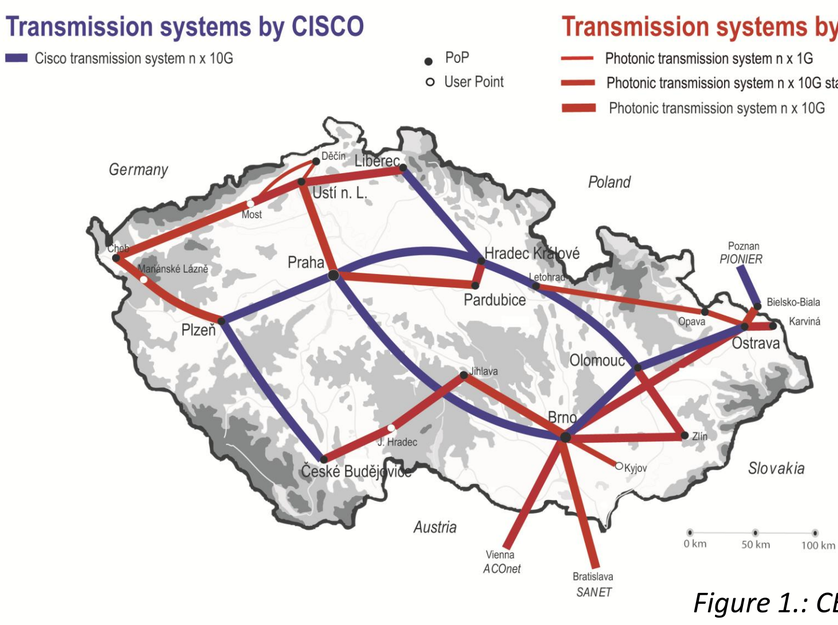

Figure 1.: CESNET2 topology

Photonic Networks

To accommodate emerging real-time applications with their various requirements network have to follow the newest trends in optical networking and deploy the cutting edge technology.

• All-Optical network Nodes

The main feature of proposed photonic network is all-optical nodes that allow optical bypass and dynamical photonic-path formation. The key photonic network node element is Reconfigurable Optical Add-Drop Multiplexer (ROADM) that allows adding and dropping of Lambdas purely in optical domain.

• Dark Fiber Infrastructure

Another feature is dark fiber infrastructure that is important for multiple photonic-paths formation over available network. The availability of broad fiber bandwidth is important to accommodate services for various users.

• Network Management System (NMS)

And lastly agile network management system that is necessary for photonic-path formation throughout the network. Photonic-path monitoring and management are another examples of duties of NMS.

CESNET builds its network with mentioned features that allow demonstration of novel real-time applications. Topology of network CESNET2, that is supporting real-time application, is on *Figure 1*. CESNET2 combines network solution from two vendors and proves that photonic network can be also built in multi-vendor environment. Although transmission platform based on Cisco DWDM is used for the backbone network, where higher channels counts and higher speeds are necessary, the CzechLight family is based on of open photonic devices that are generally used where the number of channels should be easily tailored and upgraded. Open devices can offer some important advantages. Just one of them is interesting economical aspect (reduction in CAPEX and OPEX).

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Real-time High-definition 3D video broadcast

Cave-to-cave and HD video have recently enabled doctors and students of medicine to see the real-time high resolution video of operation by their own eyes and enjoy the precise work of top surgeons in the world. These high bandwidth demanding application require a dedicated Lambda to provide users with full experience. Also demands of application on the latency are in orders of milliseconds. Actually a practical demonstration of HD video transfer has been accomplished in the Czech Republic (*Figure 2*) over dedicated 10Gb/s link on the distance of 150km. The data stream reached transfer speeds of approximately 2.5 Gb/s and the signal delay along the transmission stream was less than 1 ms, enabling a truly real-time broadcast [I].

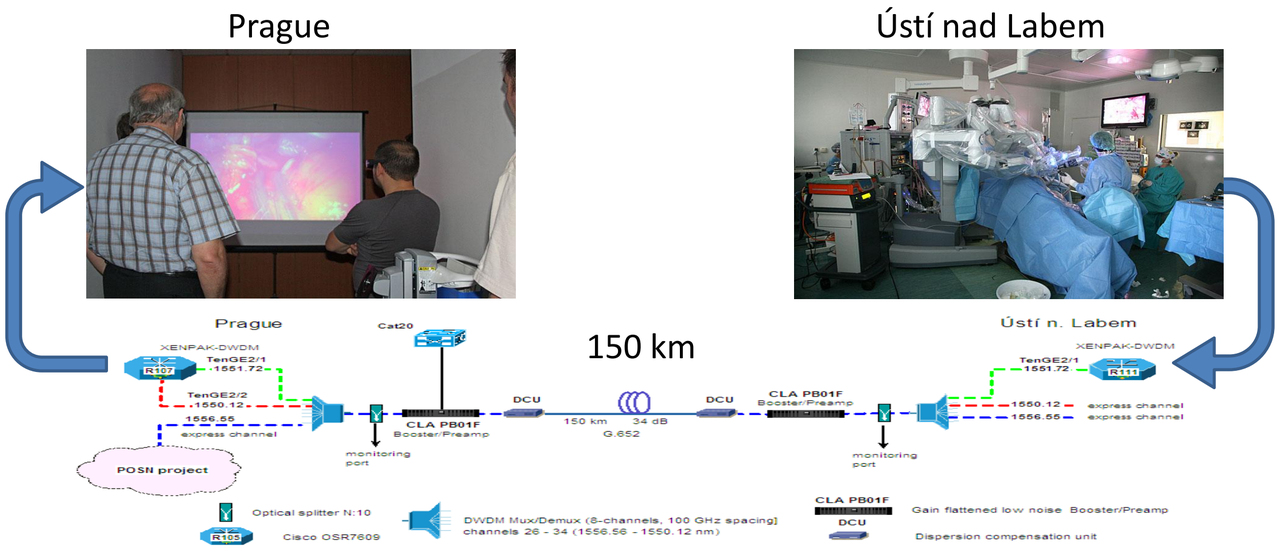

Figure 2.: Real-time high-definition 3D video broadcast

Demanding network applications

New unique instruments and facilities are often built at the most suitable places in the world that may not be well accessible. To name just a few see the unique observatory in India, that was built over 4500 meters high above the sea level in the barren desert of Ladakh [II], or highly specialized robot-assisted surgery system da Vinci located just in the most specialized hospitals in the world [III]. The remote control of such instruments can save time and expenses to relocate experts to work directly on the site. The hospital in Strasburg conducted a Tele-surgery already in 2001. The robotic surgery connected the top surgeon from New York to the patient in Strasbourg [IV]. The most recently, professionals of CESNET and Masaryk Hospital in Ústí nad Labem have demonstrated their experience with transmission of robotic operations to their colleagues in Japan [V]. The time standard is usually provided by cesium clock and then distributed all over the country. The comparison of different clocks was preferably done by radio signal over satellites that required complex instruments. Advances in optical networking opened a new comparison option by utilization of light pulses that are timed precisely once per second with resolution in order of tens of nanoseconds [VI]. Latency requirements of this new comparison technique can be met just by optical bypass in network nodes that do not introduce any variable delay. Photonic nodes overcome the limits of electronic in standard nodes and are a substrate for new advanced applications. This fact is also recognized by GÉANT network engineers for future network planning [VII].
In general a successful photonic network for real-time service should respond to an event within a predetermined time and there has to be defined the penalty for not meeting such deadline. These network constrains can be described as timeliness and reliability [VIII].

References

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Conclusion

We presented future-proof concept of a photonic network that allows real-time applications. Three features have been identified as a crucial for photonic network. They are purely optical nodes, dark fiber infrastructure and network management system. Moreover we overviewed demonstrations of novel network applications like real-time high definition video broadcast or atomic clock comparison, that were carried out in our network CESNET2. We also highlighted the importance of NRENs in allowing applications that wouldn't be possible with ISPs. The boom in photonic networking is expected with the advent of complete signal regeneration in optical domain that will overcome the transmission distance limit of pure photonic network of several thousands of kilometers. Until that time the reach of photonic-path will be limited by optical noise.