Innovative photonic devices for emerging NRENs

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Abstract

We present a conceptual paper about photonic networks and devices for emerging NRENs. The fundamental difference between NRENs and ISPs is highlighted and non-standard applications for optical networks are discussed. We introduce open approach for network devices, where their advantage in NRENs optimization is explained. We identified three optical network development approaches that bring considerable savings for NRENs. At last, all-optical networks are found as a way into future and should be supported by NRENs.

Keywords

Photonic devices, Open networks, Customer Empower Fiber networks, Nothing-in-line, Single fiber bidirectional system, Czech Republic

1. Introduction

1.1 NRENs

The incredible rate of today's innovation can't be followed without global communication and that is place where National Research and Education Networks (NRENs) come into play. Supported by local government and global projects NRENs deliver internet connection to nonprofit partner organization like universities, research institutions and also hospitals and schools. It is important to highlight that NRENs are not competitors to Internet Service Providers (ISPs), because beside the internet connection their main aim is to provide collaborative and educational environment that allows adoption of the latest learning methods and extensive training local students [1]. Such environment must provide also network applications that are not cost-effective, and therefore not supported by ISPs, but are requested by Research and Educational Community (REC). Moreover NRENs usually help minimize distance and digital divide by offering services to all partners at the same price.

1.2 New applications

Access to the Internet obviously opens new ways to find and acquire information, but NRENs can utilize their networks to provide applications beyond means of the Internet. Connected

NRENs can enhance end-to-end collaboration by forming a photonic channel that allows special applications. Some of them can be delivering large data flows during real time High Definition (HD) video broadcast. Such real time broadcast was set up across 150km to connect the unique Da-Vinci Robot [3] in a Hospital with lecture room of medical university [2]. Students were able to communicate with a surgeon during the operation in real time and discuss details of operation, see Figure 1. Such extensive training translates into improved level of graduate students. Similar robotic applications can be conducted also over thousands of kilometers and between continents [5]. Clearly such new applications that are not yet supported by ISPs, drive innovations further [6]. We may expect more novel applications in specific environment of Africa continent.

2. Open photonic network devices

A communication network that is required by REC should flexibly react to community needs to fulfill its role. Flexibility of networks strongly depends on expertise of NREN staff and nature of the network. Expertise can be gained from proper training in networking, but hands-on experience is best obtained by practice with suitable hardware. Most optical network vendors deliver turn-key systems suitable for telecommunication operators that look for maximum network capacity at account of its customization and flexibility. Also a network that allows nothing more than network of ISPs and telecommunication operators can be easily considered a competition to private sector. Therefore the added value of NREN should be evident. It translates into nature of network that is best shaped if network devices are open to modifications and allows adding the value through new services for REC. The openness of our photonic network devices could be referred to similar approach as in open sources, open standards and open information [7]. This approach ensures access to all information about device and creates opportunity for end-users like NREN experts to customize it to suit whatever application is requested by REC. Open photonic network devices have modular design so any part can be replaced by latest model or desired manufacturer. All technical documentation is freely available and supported by community. We designed CzechLight, a full family of network devices that can form optical network following latest trends [8][9].

1.1 System optimization & Cost-effectiveness

It is essential to stress that as NRENs has different mission than networks of telecommunication operators also their networks could be built differently to achieve NRENs goals. Obviously ISPs aim for maximum network capacity to increase their profit, but NRENs usually experience lower traffic and need to react quickly at REC requests. Since network vendors design their systems for ISPs, we found that optical networks optimized for NRENs are slightly different from their commercial counterparts. Such optimization brings saving in both Capital Expenditures (CAPEX) and Operational Expenditures (OPEX). We identified three main approaches for NREN optimization.

1.2 Customer Empowered Fiber network (CEF)

CEF represent approach in building of optical networks entirely according to wishes and possibilities of customer. The fundamental resource in optical network planning and development is fiber infrastructure. It is essential for NRENs that their network is based on dark fibers. A dark fiber means that an NREN has full access and control over optical fiber and can deploy any technology at it, particularly the technology that suits NREN the best. This approach allows NREN to build on top of dark fiber infrastructure a future-proof network that is flexible to REC requests. Although fiber plant of African countries may not be yet fully developed, it is worth of noting that in Europe the majority of fiber cable deployment cost is for labor work. CEF networks workshops are periodically held every two years in Czech Republic discussing advances and challenges of optical networking [10].

1.3 Nothing-in-line (NIL)

Most vendors have their optical systems optimized for maximum capacity and customer has to provide housing for network equipment every 80 km [ref]. Such request can be complicated or even impossible in some places. It might be challenging to provide secure housing with electricity in the middle of barren land [11]. It is essential to point out that 80 km can be easily overcame and transmission over single span of 200 km has been successfully demonstrated [12]. Moreover majority of optical network of CESNET, NREN of Czech Republic, has fiber spans in range of 100-200 km. CESNET developed photonic network devices, called CzechLight, to support as long spans 200 km and offer technology transfer to other NRENs.

We see great potential in this approach for emerging African NRENs that usually needs to connect distant places with minimal CAPEX and OPEX.

1.4 Single fiber transmission (SFT)

Although technology for bidirectional SFT is commercially available for quite long time, it is seldom deployed in field. It is mainly because market is oriented for ISPs needs and there is usually large fiber plant available. Still annual rental of fiber pair in central Europe is about 0.5 EUR/meter/year [13] and rental of a single fiber comes at 60% of price of fiber pair. An annualized cost of commercial transmission system is about 0.12 EUR/meter/year for 4 years amortization and 10 Gb/s transmission rate and from 0.035 to 0.047 EUR/meter/year for open transmission systems [13]. Bidirectional SFT has just half the capacity of fiber pair, but if you consider more than 70 optical channels, at 100 GHz grid, just within C-band then one can easily have 350 Gb/s data flows in both directions with well matured 10Gb NRZ transceivers. Since that capacity is hardly to be required by any NREN, we believe that bidirectional SFT is a promising approach for emerging NRENs with limited resources.

3. The way to all-optical networks

Once NREN acquire dark fiber infrastructure it is up to them to select whatever they will use open, commercial or multivendor systems. Clearly commercial systems allow just features that are vendors aware of and are prone to fast modifications for REC requests. In contrast open systems permit any modification and give full hands-on experience to NREN experts that can shape the network according to current needs. Therefore it is possible to form truly all-optical networks that can establish light-path between any locations in network. Such network satisfy even the most demanding REC requests as atomic clock comparison [14] and is suitable for any other application with strict requirements on latency jitter. All-optical networks are limited in their reach by lack of all-optical regeneration that still remains a challenge for research community.

4. Conclusion - Optical networks that suits Africa

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We emphasize the role of NRENs as the leading institutions in supporting of REC and breaking the digital divide. These activities translate into better education of local experts and hands-on experience with emerging technologies that in long run increase overall standard of living. We introduced open photonic devices that are suitable for building of cutting-edge photonic networks with enhanced flexibility. Following the three above mentioned approaches, we can claim that CAPEX and OPEX of optical networks can be effectively cut down with careful planning and proper network equipment. These approaches may be considered by emerging NRENs to ease their start or early development. A few novel applications were described to show the big potential of optical networking.

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Biographies

Pavel Škoda joined in 2005 the project "Components for high transmission rate all-optical networks" at the Institute of Photonics and Electronics at the Academy of Sciences of Czech Republic. He graduated in 2008 at the faculty of electrical engineering of the Czech Technical University in Prague. After graduation Pavel went to the Tyndall National Institute in Ireland to study the dynamics of mutually coupled laser system. Since 2009 he has been working at Optical networks activity in CESNET z.s.p.o. in Prague. In 2010 Pavel started the Ph.D. study at the Czech Technical University in Prague.

Jan Radil received the M.Sc. and Ph.D. degrees in electrical engineering from the Czech Technical University, Praha, in 1996 and 2004, respectively. Jan joined the Research and Development Department, CESNET, Praha, in 1999, where he is responsible for optical networking and the development of the next generation of the Czech research and educational network. Jan participated in the EU projects SEEFIRE, Porta Optica Study, Phosphorus, GN2 and GN3.

Stanislav Šíma holds Dipl. Ing. (1967) and PhD. (1983) degrees from Czech Technical University (CTU) in Prague, Faculty of Electrical Engineering for the study of formal semantics of computer systems. He joined CESNET in 1996. Since 2000, Stanislav has been leading the CESNET research activity in optical networking. He is promoter of Customer Empowered Network concept for R&D networking and he has great experience with building of lit fiber infrastructure not only national but also international level. Recently, he has been involved in SEEFIRE, Phosphorus, Porta Optica Study and GN3 projects.

Josef Vojtěch joined Research and Development Department of CESNET, a.l.e., in 2002, where he is active in applied research in the area of photonic networking. He received the M.Sc. degree in Electrical Engineering and B.Sc. degree in Pedagogy from the Czech Technical University, Prague, in 2001 and 2003, respectively. In 2009 he defended his Doctoral thesis "All-optical networking" at the Czech Technical University in Prague. In Scopus, 24 records have been found with 29 citations, h-factor was 3.

Lada Altmannová holds Dipl. Ing since 1983 from Czech Agriculture University in Prague, Faculty of economy. She joined the Computing centre of this University. She joined CESNET since 1996. She was Head of Financial department and since 1999 she is deputy of Head of Research and development department. She is interested in dark fibres lines for CESNET2 and CzechLight networks and has extensive experience of wavelength and fibre procurements on national level. Since year 2000 she was responsible for transformation of CESNET2 from wavelength service to dark fibre lease.

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