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Programmable Optical Signal Transmission and Processing for Flexible Optical Networks

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Abstract— The technologies incorporating optical fibers and smart optical fiber based devices are essential for future flexible all-optical network to enhance the transmission capacity and processing efficiency. We will demonstrate our works in this presentation about flex-grid tunable optical filter, flexible wavelength selective filter, space-wavelength division flexible optical transmission and all-optical fiber based signal processing in spectral or temporal domains.

Flow Aggregation and Migration Scheme Based on Real-time Monitoring for Time-varying Traffic in Optical Networks

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Abstract— Nowadays, the transport network is experiencing a challenge of bulky data transfer for large-scale applications, such as E-science computing, data center data back-ups and cloud services [1]. When these applications require high transmission rate (e.g., 10 GE or more), a lightpath with guaranteed bandwidth provided by optical circuit-switched networks becomes an effective solution to meet application performance requirements, such as bit rate, packet loss and latency. However, the bandwidth of a lightpath is often underutilized. A major reason is that flows generated by applications may have a time-varying bandwidth demands, typically, higher traffic volume during daytime and lower traffic volume at night. If a lightpath is dedicatedly used by a flow, this may lead to bandwidth resource waste when flow rate becomes low.

In order to make better utilization of bandwidth resources, we proposed a flow aggregation method implemented by an extended SDN controller [2]. This method is to aggregate multiple fine-granularity flows into a lightpath, whose bandwidth resources have not been fully utilized. In this way, these flows can share the same lightpath and lightpath bandwidth utilization increases. However, the transmission rates of flows vary frequently over time. If the total transmission rate of the flows exceeds the bandwidth of the lightpath, packet loss will occur and transmission quality of flows will degrade.

In this paper, we propose a flow aggregation and migration scheme (AM) based on real-time monitoring to improve bandwidth utilization while guaranteeing transmission performance of the entire network. Our method is to aggregate some fine-granularity flows (with low-priority) into a lightpath with spare bandwidth resources. To guarantee transmission performance, the low-priority flows will be migrated into another lightpath when bandwidth resources of the original lightpath are used up. Since flow migration needs time, we set a threshold to control the maximal load in the lightpath. Once the overall flow rate exceeds the threshold (but still less than the bandwidth of the lightpath), flow migration will be executed to reduce packet loss. Due to the flexible programmability of SDN controller to flow, we can easily complete the flow aggregation and ow migration. We have tested the performance of our extended controller on our testbed. Experimental results show that our extended controller can migrate a flow from one lightpath into another in 2 seconds, with no influence on data transmission delay and packet loss of the original flow (with high-priority). In addition, we can reduce the packet loss of low-priority flows by reducing the threshold. We also conduct simulations, which illustrate that our AM scheme improves the lightpath bandwidth utilization and reduces the blocking rate.

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Experimental Demonstration of 100-Gb/s TWDM-PON

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Abstract— With the wide spreading of internet-based services such as online video, cloud computing, etc., demands on the capacity of optical access network is growing continuously. Time and wavelength division multiplexed passive optical network (TWDM-PON) based solution for next generation PON stage 2 (NG-PON2) is being discussed and will come to a conclusion in the near future. A lot of 40-Gb/s TWDM-PON system demonstrations have been reported, providing a variety of technical candidates for practical applications [1–3]. However, for further capacity upgrade, e.g., 100-Gb/s TWDM-PON, the technical proposal is still open for discussion, where cost-effective transmitter with 25-Gb/s capacity is a key component. Some research institutions are making efforts to increase the modulation bandwidth of both external modulators [4] and directly modulated distributed-feedback lasers (DFBs) [5]. On the other side, advanced modulation formats with high spectral efficiency have been proposed to realize high data rate modulation on bandwidth-limited transmitters. A 4×25 Gb/s four-level pulse amplitude (4-PAM) modulation using 10-GHz devices have been demonstrated [6]. Besides, a symmetric 100-Gb/s TWDM-PON, where double sideband (DSB) orthogonal frequency division multiplexing (OFDM) was used in both upstream and downstream directions has been presented [7]. However, high sampling rate ADC/DAC are required in these systems which increases the difficulty and cost for real-time signal processing.

In this paper, we present 25-Gb/s operation of a commercial 10-GHz directly modulated DFB laser (DML) and PIN. Non-return to zero on-off-keying (NRZ-OOK) instead of advanced modulation format is used, which significantly simplifies the digital signal processing (DSP) module. In order to increase the modulation bandwidth, we employ a delay interferometer (DI) following the DML to equalize the modulation response. Simultaneously, the DI narrows the optical spectrum of the directly modulated signal and realizes chirp and dispersion management during fiber transmission. As a result, 40-km standard single mode fiber (SSMF) transmission is demonstrated with bit error ratio (BER) lower than 1×10^{-3}, which provides a cost-effective solution for 4×25-Gb/s TWDM-PON systems.

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Advancements in Next Generation Broadband Optical Access Networks

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Abstract— The Internet has become an indispensible part of our modern society. Development in broadband access networks are directly connected with economic growth and prosperity of societies. Companies are foraying into new technologies for next generation broadband systems. In this talk, we review the challenges and advancements in next generation broadband optical access network developments.

Impact of Protection to Converged Access Networks Planning in Rural Areas

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Abstract— Network operators are reluctant to offer broadband access in rural areas due to the high investments and limited revenues. Protection in those areas is even more critical and hence, not yet considered by operators. One alternative to decrease costs in rural areas is the use of new architectures such as Hybrid Passive Optical Network (HPON). These architectures offer several advantages not only from the longer reach and higher client count, but for the possibility of offering different bandwidth per end point. The recently proposed HPON architecture could be used to offer more bandwidth to the base stations (10 Gbps) and less bandwidth to residential users (300–500 Mbps). Recent work has presented a detailed framework that using real building and street data provided by OpenStreetMap allows computing the fiber layout for different access architectures and splitting ratios. The approach aims at minimizing the duct length, since costs associated to ducts and trenching have been shown to be cost drivers in access deployment. This framework has been applied in rural areas to compare the infrastructure required for a disjoint versus a joint planning. Savings depend on the building density, area size and the interBS distance. The new contribution of this paper is focused on the analysis of the cost impact of BS protection. The required availability is obtained when protection of feeder fiber and distribution fiber is guaranteed. The investment and extra fiber and duct infrastructure required for two protection schemes are compared with the unprotected scenario. The cost increase is shown to be relatively low compared with the unprotected solution.

Experimental Evaluation of Noise Impairments in Unrepeated Distributed Raman Amplified DP-16QAM SSMF Links

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Abstract— Unrepeated fiber transmissions over hundreds of kilometers span with advanced modulation formats and DSP-based coherent detection schemes are considered as a potential candidate to meet the distance and capacity requirements in certain application scenarios where render amplification sites between terminals are impractical due to geographic, commercial or security constrains [1]. Distributed Raman fiber amplifier (DFRA) ensuring a relatively constant power distribution of the optical signals along links can effectively improve the system OSNR and fiber nonlinearity tolerance, therefore is widely adopted in unrepeated transmission solutions. To date, unrepeated transmissions of 30 Gbaud DP-QPSK over 444 km [2], single and dual carrier 28 Gbaud DP-16QAM over 240 km [3, 4] have been demonstrated by using Raman amplification with large effective area fibers (LEAF). In this paper we report on a systematic experimental characterization of both the amplitude and phase impairments of the received signal induced by a bidirectional Raman pump at 1455 nm with an evaluation of the coherent transmission performances of a 28 Gbaud DP-16QAM signal in a standard single mode fiber (SSMF). The Raman induced amplitude and phase noise on the received 1550 nm signal is directly measured and the discussions around the operational rules and limitations are presented considering the inter-relation between pump power, signal OSNR and induced noise. Furthermore, performances of different carrier phase recovery algorithms, including decision-directed phase-locked-loop (DDPLL) [5], blind phase search (BPS) [6] and a two-stage QPSK partitioning [7] with variable filtering implementations in the DSP routine are investigated taking into account the specific noise profile of the received signal.

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System Aspects of 400 Gigabit Ethernet Links Using Advanced Modulation Formats

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Abstract— Today's Internet data traffic has exceeded 1 Zettabyte and continues to grow exponentially. By 2016, 90% of the global Internet/IP wide area network (WAN) traffic passes through data centers. This requires big data centers to handle the massive data traffic based on high speed optical data links. Considering the high volume of such short haul data links and optical transceivers in data centers, cost- and energy-efficiency is the critical consideration for implementations. As a response, the IEEE 802.3 created the IEEE P802.3bs 400 GbE Task Force on May 2014 and agreed objectives for both single-mode fiber (SMF) and multimode fiber (MMF) links. The distances considered include 100 m over MMF, 500 m, 2 km and 10 km over SMF. For such applications, conventional non-return-to-zero (NRZ) becomes very demanding on the transceiver bandwidth. Alternatively, advanced modulation formats with high spectral efficiency are promising solutions to achieve high data rate by using relatively less advanced components. The 400 GbE Task Force is still open to the choice of modulation format and number of wavelengths per fibre, four-level pulse amplitude modulation (PAM4) with eight wavelengths at 50 Gb/s as well as PAM4 and orthogonal frequency division multiplexing (OFDM) with four wavelengths at 100 Gb/s per wavelength dominate the debate. I addition to PAM and OFDM, there have been high speed short reach optical links demonstrated by using other advanced modulation formats such as duobinary, carrierless amplitude and phase (CAP) modulation, and quadrature amplitude modulation (QAM). This paper aims to review a wide range of implementation options for 400 Gigabit Ethernet using advanced modulation formats that have arisen in recent years. Simulations are provided to compare the system optical link power budget over both directly modulated laser and externally modulated laser based SMF links.

Programmable Photonics in Data Centers: Architectures and Algorithms

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Abstract— The recent evolution of the Internet is characterized by the need to dynamically share physical resources like storage, computing capacity and networks themselves, thus enabling modern applications, like social networking, cloud computing, video streaming and others to efficiently perform their service.

Data centers are emerging as aggregates of increasingly powerful physical facilities which generate high amount of traffic and consume high power, accordingly. In spite of the continue increase of peak performance, the allowable power consumption is required to increase at a much slower rate [1].

As a consequence, data center interconnection design will result one of the most challenging networking problem in the next future which can be solved in a massive adoption of new technological solutions, possibly based on silicon integrated photonics.

On the network service side, the evolving characteristics of content providers call for enhanced dynamic network reconfiguration capability. Emerging photonic technology can provide interconnection at extremely high rates with enhanced flexibility in spectrum sharing [2]. At the same time network control and management technologies should be able to exploit this flexibility in relation to cloud-based application dynamics.

Solutions based on combinations of Network Function Virtualization (NFV) and Software Defined Networking (SDN) can achieve the extreme flexibility required to support current and future development of cloud computing paradigms. Programmable features of emerging photonic technology can be fruitfully exploited in this context thus defining new roles and chances for optical interconnection both in capacity exploitation and energy efficiency perspective [3]. In any case the joint deployment of photonics and SDN to fulfill future dynamic network requirements, needs algorithms and architectures to harmonize and optimize several functionalities [4], which are addressed in this presentation.

The application of standard protocols like Open Flow must be studied to map network management functionalities on programmable photonics. Different approaches can be adopted based on protocol extensions or on protocol compliance. Architectures and algorithms to support the management of flexible grid channels are here considered through possible virtualization of photonic network elements based on emerging SDN protocols. Solutions to optimize the usage of wavelength channels will be also discussed in terms of procedures and performance.

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