Demonstration of Real-Time Modulation-Adaptable Transmitter

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Abstract  We demonstrate a 26 Gbaud real-time quick-reconfigurable 16QAM/QPSK-adaptable transmitter. The modulation format can be switched in less than a second by an RMAT agent. The FPGA-driven reconfigurable transmitter can work as a generic edge-node interface for traffic aggregation.

Introduction

Elastic optical networks (EONs) promise a better network resource utilization by removing optical grid limitation existed in fixed-grid optical networks and adding flexibility in spectrum bandwidth allocation\(^1\). One of the key enabling technologies for EON applications is bandwidth variable transmitter (BVT), which could generate an optical signal with variable operation baud-rates to fill up bandwidth-flexible optical spectrum slots. Furthermore, BVT should also be capable of adapting the signal’s modulation formats for different transmission reach. On the other hand, the emerged network convergence requires an edge-node interface to handle different traffics from either data centers, metro networks, or back-haul applications\(^2\), and provide just-enough-bandwidth optical signals after traffic aggregation. In addition, quick reconfigurable optical transmitter is one of the key devices for instant network optimization.

Thanks to the programmability and computing power of FPGA, a network function programmable node can be implemented by switching-over the internal FPGA functions through look-up tables\(^3\). The vast computing resource in FPGA could process and aggregate different network traffics for further transmission. A real-time baud-rate adaptable transmitter was demonstrated for optical transport network traffics\(^4\). However, to the best of authors’ knowledge, modulation adaptability have not been demonstrated in real-time.

In this paper, we implement and demonstrate a real-time modulation-format adaptable transmitter (RMAT) based on a high-performance FPGA. The FPGA parses the incoming traffic and drives the modulation-adaptable transmitter. With a quick-reconfigurable auto-bias controller, the modulation-adaptable transmitter can switch its modulation format between 16QAM and QPSK in a second. Both the FPGA and the transmitter are controlled by a local agent (RMAT agent) to adapt the optical signal modulation format. The modulation-adaptable transmitter can be potentially integrated with a SDN controller. A fully SDN-enable BVT can be used for network optimization in optical networks.

Generic Edge-Node Interface for network convergence

![Fig. 1: Architecture of the generic edge-node interface](image)

Figure 1 shows the architecture of the generic edge-node interface with the quick-reconfigurable transmitter. To provide the flexibility and the requests for future network convergence, the edge-node interface will take advantage of the huge IO resource and hardware programmability of FPGAs. Through low-speed transceivers, the FPGA could process the incoming traffic from OTN (Optical Transport Networks), Ethernet, access, data center and other networks. Then the FPGA could use its computing power to perform traffic parsing, protocol framing/mapping, traffic aggregation, and other operations. Then the processed traffic data will drive the BVT to generate optical signals for transmission towards EON. The capability to reconfigure modulation format could provide signals with flexible optical bandwidths and also accommodate the signals for different transmission distances. An RMAT agent controls both the FPGA and the transmitter to achieve the modulation-adaptability operation. The generic edge-node interface serves as an aggregating point to converge multiple network traffics to EON.
Experimental Setup of modulation-adaptable transmitter

The developed modulation-adaptable transmitter is implemented based on FPGA programmable electronic prototype (Xilinx virtex-7 580HT). With 23 × 10.7 Gbit/s high-speed transceivers (GTH), the generic edge-node interface can handle the incoming traffic over 240 Gbit/s. One GTH transceiver is used for RMAT agent to control the modulation format. After the internal FPGA processing, the traffic will be sent out through 2 serial high-speed transceivers (GTZ) with line rate up to 27 Gbit/s. The internal FPGA function blocks for traffic processing is shown in Fig. 2. The GTH traffics are converted to up to 27 Gbit/s signals to further drive the modulation-adaptable transmitter. The internal block for modulation switchover control is also shown in Fig. 2.

Experiments and Discussion

As shown in Fig. 3, the generic edge-node interface with RMAT is characterized with a polarization-diversity coherent receiver. The modulation-adaptable transmitter generates 26Gbaud PM-QPSK/16QAM signals. The operation baudrate is limited by the used clock doubler with a maximum bandwidth of 26GHz. Then an 80 Gs/s four-channel real-time oscilloscope with a bandwidth about 33 GHz sampled the electronic signals to digital signals for further digital signal processing. The offline processing performs normalization, polarization de-multiplexing, frequency offset compensation, carrier phase estimation, and LMS filter for performance optimization. Then symbol detection and bit-error ratio counting are followed for the performance test.
Figure 5(a) shows the measured spectra of both PM-16QAM and PM-QPSK signals. The spectrum of the PM-16QAM signal shows low side lopes than that of the PM-QPSK signal, due to the relatively low voltage of the 4-level signals. The corresponding electric eye diagrams for both QPSK and 16QAM signals are shown in Fig. 5(b) and (c). The noisy eye diagram is partly due to the used out-dated oscilloscope with bandwidth less than 50 GHz.

The received signal distributions are shown in Fig. 5(d) and (e) for PM-QPSK and PM-16QAM signals. Assisted by two DFFs, the output signals of the FPGA serial transmitters are improved a lot, and lead to high-quality signals. By adding extra ASE noise to the signal, we tested the OSNR vs. BER curve and showed the results in Fig. 5(f). The required OSNR to achieve BER = 3.8E-3 (7% FEC threshold) is about 20.3 dB and 15.36 dB for PM-16QAM and PM-QPSK signals. Regarding quick reconfiguration of modulation format, we use optical spectra as an indicator for stable bias controlling. The auto-bias controller recorded two sets of the bias parameters for both QPSK and 16QAM, thus the corresponding parameters can be retrieved in advance. Without the locking time, the bias controller can switch its operation status quickly. The auto-bias controller is aslo controlled by the developed RMAT agent. The captured agent communication messages in Fig. 4(c) confirmed the RMAT agent figures the modulation-adaptable transmitter successfully. Including the switching time of the bias controller, the preliminary test shows the modulation adaptability can be performed in less than one second.

**Conclusion**

A 26 Gbaud FPGA-driven real-time modulation-adaptable transmitter is demonstrated real-time successfully. A local RMAT agent configures both the auto-bias-control board and FPGA to reconfigure the modulation in less than one second with stable outputs. The FPGA-based modulation-adaptable transmitter provides both network function programming and optical signal flexibility, which can work as a generic edge-node interface for elastic optical networks. The instant modulation-adaptability could be used for real-time optical network optimization.

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**References**


