Green and Agile Petabit Optical Sub-wavelength Switching Prototype for the Future OTN Multi-Chassis Switch Cluster

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Abstract: A proof-of-concept prototype of optical sub-wavelength switching fabric is demonstrated. The prototype supports petabit switching capacity with agile service granularity and low power consumption.

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1. Introduction

Nowadays, Optical Transport Network (OTN) plays most important role in multi-service switching such as voice and data service in networks node [1]. Especially, in the era of the Cloud Computing, OTN switching can support more Virtual Optical Network (VONs) to help providing Infrastructure as a Service (IaaS) for worldwide networks and telecom operators.

As the traffic increases, the optical transport network nodes will need ultra high OTN switching capacity. The solution of switch cluster which connects multi-chassis together seems to be the only way to achieve the ultra high capacity. The main drawbacks of the switch cluster are huge power consumption and massive interconnection fibers [2]. Thus, the future OTN switch cluster is supposed to evolve to character ultra large switching capacity, lower power consumption, fewer interconnection fibers and non-blocking switching at multi-granularity.

Recently, optical sub-wavelength switch fabrics attract much research interest [3]-[4]. Switch speed and ultra large switch capacity are the most important in sub-wavelength mechanism at networks nodes. However, fast switching and ultra large capacity are hard to simultaneously realize [5]-[7]. In this paper, we propose a proof-of-concept prototype demonstration of 1Pb/s optical sub-wavelength switching fabric featuring green power dissipation and agile granularity for the future OTN multi-chassis switch cluster. The prototype could support 324-chassis OTN switch cluster with up to 1Pb/s capacity at minimum granularity of 1.25 Gb/s (ODU0).

2. Prototype Architecture and Experimental Experiments

The traditional multi-chassis switch cluster is realized as the Fig.1 (a) depicts. To avoid the OEO conversion, optical switch is proposed in recent years. The proposed prototype architecture is depicted in Fig.1 (b). In each switching plane, it includes a three-stage-Clos architecture: stage-1(S1) and S3 is composed of fast tunable laser (FTL) transmitters and burst mode receiver respectively, both of which are located on the same line card of cluster line-card chassis (CLC). The S2 employs a sub three-stage-Clos architecture, realized by fast optical switch (FOS) and array waveguide gratings (AWG). 324 CLC chassis are linked by the FOS and AWG, both of which are located in the cluster central chassis (CCC).

The ingress data are packed into burst signals and modulated on different wavelengths of FTLs. The line card photo is shown in Fig.1 inset(a). There are 8 optical bursts (OBs) in a frame with total length of 125µs. Each OB contains preamble, delimiter, overhead and payload. The wavelength switching time of FTL is 98ns (rising time from 10% to 90%) with 12.5G bit rate. The OBs waveforms and 12.5 Gb/s eye diagram are shown in the Fig.2 (b)-(c). The used FTL is fabricated in Oclaro company based on the digital super-mode distributed bragg gratings (DSDBR) technology, which covers 91 ITU-T center wavelength from Ch6-Ch96. In Fig.3 (a)-(c), we record the three set of emitting wavelength of FTL from short, medium and long range of C-band, which demonstrated the FTL’s full band covering capability.
Fig.1 (a) Traditional multi-chassis switch cluster electrical solution (b) proposed solution architecture; inset (a) line card of FTL and BMR inset (b) line card of FOS; inset (c) line card of AWG.

In S2, the 4×4 FOS are cascaded by 4 pcs 2×2 FOSs provided by the BATI company, which have the switching time less than 60ns with its line card photo shown in Fig1 inset (b). The 81×81 AWG is based on the uniform loss cyclic frequency (ULCF) that benefits from mitigating the center frequency mismatching effect in normal AWG with its line card photo shown in Fig1. inset(c). Fig.3 (d) shows the output spectrum by injecting broad bandwidth light from one input port. The 81×81 AWG has frequency space of 50GHz, the The insertion loss is approximately 10.5dB.

Fig.2 (a) data frame structure schematic (b) OB waveform (c) 12.5 Gb/s eye diagram

Fig.3 (a)-(c) FTL spectrum of Ch6-13, Ch54-61 and Ch89-96 (d) AWG output spectrum by one input broad bandwidth light

We measured the optical link BER performance analysis. The ingress data from the BER analyzer are packed into burst signals and modulated on different wavelengths of FTLs, the waveform is recorded in Fig.4 (b). In S2, the OBs signals are optically path switched to different 81×81 AWG. Different OBs are routed to different outputs of AWG according to wavelength path and the waveform is shown in Fig.4 (c). Then, the OBs return to the burst mode receiver via FOS and are unpacked to service to measure the BER performance. The optical link loss is about 27dB, including 9dB insert loss at double FOS, 10dB at AWG and total 8dB interface loss. The optical power of the FTL is
0 dBm and the received optical power is about -27 dBm after the transmission. Experimentally, the prototype was tested for error free operation over 24 hours at a line rate of 12.5 Gb/s, with OB guard time of about 400ns (more than 98ns switching time of FTL). We used 7% forward error coding (FEC), so we get about 2dB margin. The higher bit rate (14 Gb/s, 25Gb/s and 28Gb/s) of interconnection are also analyzed by VPI transmission maker system simulation, as shown in Fig. 4(d). The simulation results exhibit that the higher bit rate corresponds to the worse BER performance, because signals are degraded by passed flat width limited of AWG.

3. Analysis of cost and power consumption and future evolution

In this section, weanalyze the cost and power consumption characteristics of the prototype and the equal capacity scale electrical solution. The FTL is the key component of CLC with high cost and power consumption than normal DFB or VCSEL module but FTL could possess switching function that not exist in DFB or VCSEL module based solution. In the prototype phase, the FTL price is as high as $2500 because of device customization in small volume and high power consumption by reason of high performance FPGA and strict low temperature stabilization circuits. As the fabrication easing and normal circuit employment in the future, we described the FTL evolution on price and power consumption from year 2012 to 2017 based on some related optical component company’s reasonable foreseeing, shown in Fig. 5(a) and Fig. 5(b). Furthermore, we calculate the total cost and power consumption of our prototype and the electrical solution for multi-chassis cluster-switching. The prototype’s advance than electrical solution in cost and power consumption will emerge as the FTL evolution. We also could infer that further reduction of cost and power consumption will be realized by the optical switching module’s development such as N × N monolithically integrated chip to replace the cascaded 2×2 FOS architecture.

5. Conclusion

A proof-of-concept prototype of optical sub-wavelength switching fabric is demonstrated. The prototype supports petabit switching capacity with agile service granularity and low power consumption. On reasonable prediction, the proposed optical solution has bright future in future OTN Multi-Chassis Switch Cluster.

6. References