Transmissions and Network Management of Multiple 100 GB/s Based on Stacking Technology

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Abstract. We have previously proposed and implemented a small form factor and low cost 100G optical transmission system using inverse-multiplexing technology and MLD (Multiplex-Lane Distribution) mechanism [1]. Based on this 100G system, we will further implement a transmission and network management system for multiple 100G application via stacking technology. This technology can incrementally realize the standard 100G OTN or 100G Ethernet capacity expansion with a centralized network element management at one node. The stacking system contains both network management port stacking and optical wavelength stacking. Our test results show that we can stack at least four devices with stable performance, which means a maximum transmission capacity of 400G, but with one IP address or one NE (network element) network management. This technology has a significant advantage comparing with a large rack equipment in term of device cost and flexible 100G bandwidth addition, as well as simple management function.

Keywords: 100G · Multiple 100G · Stacking · Capacity expansion
Network element management

1 Introduction

In recent years, with the advent and popularity of broadband services of the terminal users, such as 4G/5G services, Internet video, high-quality Internet Protocol TV (IPTV), cloud computing, big data, etc., the demands of bandwidth in data networks are showing the scale of exponential growth, which drives the development of high-capacity optical transmission network. Data center switch and router are upgrading to 100GbE interfaces, and the mainstream transmission equipment has developed to single-wavelength 100G capacity from 10G due to the bottleneck of 10G networks. As the support network, the transmission

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network is entering an accelerating era of 100G or beyond 100G. On current projections, the transmission capacity of metropolitan area network (MAN) will increase five-fold in 2017 comparing with 2012 [1,2].

However, how to further improve the bandwidth in backbone network and achieve the access to a variety of services are forever topics. Although beyond 100G optical transmission systems have been the hot subject of recent research efforts, remaining the immature standard and some unresolved technical problems, and it will still adopt PDM (Polarization Division Multiplexed) and fast DSP technology which is not very appropriated for low-end application.

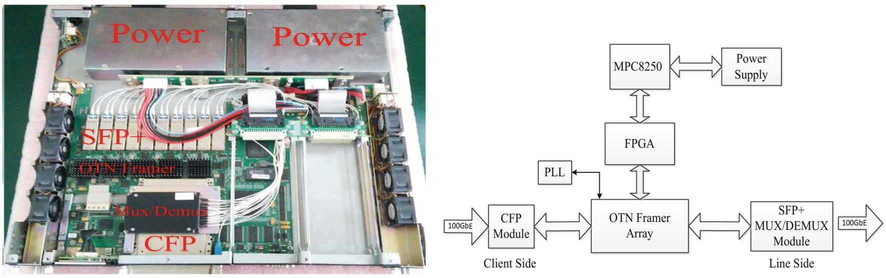
On the other hand, high-capacity optical transmission requires effective network management. A network management implementation should be capable of handling configuration, traffic, fault, alarm and security [3]. Traditionally, network element is managed independently. In the meantime, the increasing NEs (network equipment) add to pressure on network management, which will make it complicated. Therefore, it is essential to reduce the number of logical devices utilizing virtualization, through which network topology can be simplified for network management.

We have proposed and implemented a low cost 100G transmission platform which is based on Inverse-Multiplexing technology and MLD (Multiplex-Lane Distribution) mechanism [1,4]. It is an effective low cost solution for 100GE transmission in MAN, access network, especially for data center 100G interconnection applications. In this paper, in order to support application for multiple 100G transmissions on one node and do centralized management of multiple physical devices, we further propose a novel scheme to implement multiple 100G transmissions based on stacking technology. When we do network expansion based on 100G transmission platform, it will increase complexities of OAM management due to the addition of NEs. Most communication manufactures generally manage and configure network element equipment independently, which results in a waste of IP resources and makes a complicated network management system. And this traditional method just interconnects multiple devices to increase available ports, but does not reduce the logical NEs, so it cannot simplify network structure actually [5]. To solve this problem, we propose to use virtual stacking technology to realize high port density as well as unification of equipment management for beyond 100G. It is implemented by connecting multiple 100G physical devices through physical ports of stackable subcards with switch chips, and virtualizing them into single logical equipment after some necessary software configurations. It is different from the general scheme applying to a whole beyond 100G system since it can implement multiple 100G via simpler 10G technology, and stacking is usually used among switches while rarely used on transmission devices like our proposed system. The stacking system consisting of multiple devices only has one external IP/MAC address, and there is one master device and at least one slave device in the system. These devices communicate with each other via Ethernet protocol and data packet forwarding at layer two. It is notable that implementation of stacking is consisted of network management port stacking and optical wavelength stacking.

2 Experiment Setup

2.1 100G Transmission Platform

The 100G transmission platform is a low cost, 1RU device (1.75 in. height and 19 in. width), which has the most small form factor and lowest power consumption (100 W) in the world until now [1]. The prototype picture and block diagram of 100G main board are shown in Fig. 1(a) and (b) respectively. The 100G system provides 10 wavelengths for 100GE point to point and long distance transmission. It has three EDFA slots which can be any combinations of pre-amplifier and boost amplifier, and it can also support OLP (Optical Line Protection) card, FBG (Fiber Bragg Grating) based DCM (Dispersion Compensator Module) card and Band-Filter card for stacking application. 100GE traffic from switch or router is fed into CFP module by 4×25 or 10×10 WDM optical signal. In this application, CFP module is used at client side and it converts 100GE traffic to $10 - lane \times 10.3125$ GB/s electrical CAUI interface defined by IEEE 802.3ba standard [6]. For better performance and network management, ten 10G OTN frames are designed to provide FEC and PM (Performance Monitor) function. Each lane of CAUI signal is transparently mapped into 10G OTN frame, and then sent to integrated DWDM SFP+ module for electronic to optical modulation process and long haul transmission. Through SFP+, optical signals are multiplexed into one fiber via a 10-channel DWDM MUX from the transmitter, and are de-multiplexed via DEMUX at the receiver.



(a) (b)

Fig. 1. (a) Prototype picture of a 100G optical transmission device; (b) Block diagram of 100G main board

2.2 Transmission System for Multiple 100G

Figure 2 shows experiment set up for multiple 100G stacking application. It is a typical structure of two devices stacking connection, in which devices link up by up/down Ethernet ports of STK subcard. We call every 100G device as a shelf. Each shelf has its already configured shelf number which is saved in flash. According to different shelf numbers, shelfs in a stacking system can be divided

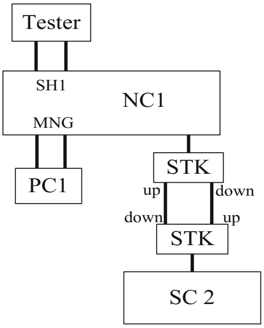


Fig. 2. Multiple 100G stacking application diagram

into NC and SC. NC is node controller and SC is a shelf controller. NC is directly operated by users which should be able to obtain necessary performance data from SC devices, and its shelf number is one. SC needs to send data to NC and its shelf number cannot be one. There is only one NC while the others are SC devices in a stacking system. In stack application in term of 100G system, the number of SC can reach three, so maximum up to 400G total stacking capacities. The stacking card STK mainly involves a highly integrated 3-port switch chip with PHYs, among which up/down ports represent stack ports, and they are physical interfaces to send or receive messages between 100G shelfs. STK subcard is presented in Fig. 3.

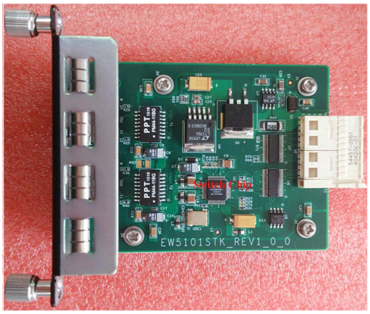


Fig. 3. STK subcard

3 Stack Application for Multiple 100G Optical Transmission System

3.1 Stack of Network Management Port

Network management port stacking refers to a method of connecting two or more physical switch chips to build a larger system that behaves as a single logical entity. Stackable and chassis network equipment are two approaches to address high port density and unified management demands. In order to support application for more 100G signals on one node instead of adding new nodes to expand capacity, the 100G optical transmission device can stack at least 4 mini-chassis, which means it can support at least 4×100G transmission traffic. Stack of network management port is the foremost part in the system which is realized by STK subcard.

The STK subcard has two 10/100M physical layer transceivers and three MAC units with an integrated layer 2 managed switch. On the media side, this module supports IEEE 802.3 10BASE-T and 100BASE-TX on both PHY ports. The two 10/100M management ports are used for network management stacking. STK subcards are attached to each stacking 100G mini-chassis through Ethernet interface, i.e., SMC (Simple Management Card) slot. And then connect UP port to DOWN port of each STK subcard in order, which makes software management and configuration management for each individual 100G mini-chassis flexible and easy. Figure 4 shows the application of network management port stacking.

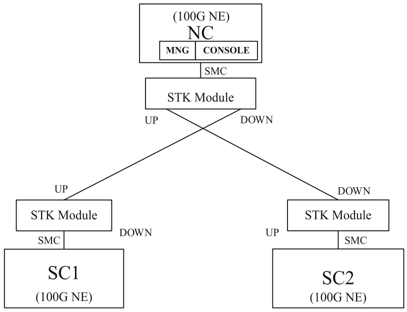


Fig. 4. Stack of network management port

In multiple 100G stacking application, the whole system has been used MPC8250 microprocessor as control unit, which provides many simultaneously available CPMs (Communication Process Module). MPC8250 has three FCCs (Fast Communication Control) and FCC1 is applied in management port stacking as the communication interface with STK. FCC supports entire Ethernet standard through MII (Media Independent Interface). In term of hardware, FCC1 is connected to SMC slot through CPLD (Complex Programmable Logic Device), and then attached to switch chip in STK module. Specific interconnection structure is shown in Fig. 5 below. The reduced media independent interface (RMII) specifies a low pin count Media Independent Interface (MII). RMII provides a common interface between physical layer and MAC layer devices. It operates in MAC mode in this connection.

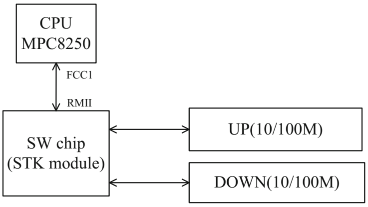


Fig. 5. Interaction between CPU and switch chip of STK

3.2 Stack of Optical Wavelength

Optical wavelength stacking is implemented by sub-band multiplexing/de-multiplexing card, i.e., wavelength band filter card. The one shown in Fig. 6 supports two sub-bands stacking. Band filter card for CWDM/DWDM platform is the new type of optical wavelength stacking application. It is a small scalable device with high-density and integrated slots. It allows the wavelength to be divided into several sub-bands and can support up to four wavelength sub-bands. Hence, numbers of 100G equipment can be stacked together for the ease of network expansion purpose. The network capacity can be enhanced up to 400G. Figure 7 below summarizes the functionality of a band filter.

Fig. 6. Band filter card

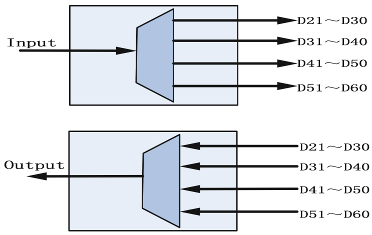


Fig. 7. Block diagram of band filter card

In example of 400G stack system shown in Fig. 8, band filter card can divide DWDM wavelengths of C band into sub-band 1 to sub-band 4, which are in accord with ITU-T G.692 [7] wavelength standard. Each sub band includes ten wavelengths and every 100G mini-chassis supports one sub-band. Therefore, four mini-chassis can be stacked to support 400G transmission. For details, at the line side, the received stacked optical signals enter into band filter card and output into four group sub-bands. The sub bands are then sent to each individual 100G shelf respectively via output ports of band filter card. Finally, ten different optical wavelengths are split through in-built DEMUX of each 100G shelf. After two multiplexing/de-multiplexing stages, four devices are stacked in one node to support maximum 400G transmission.

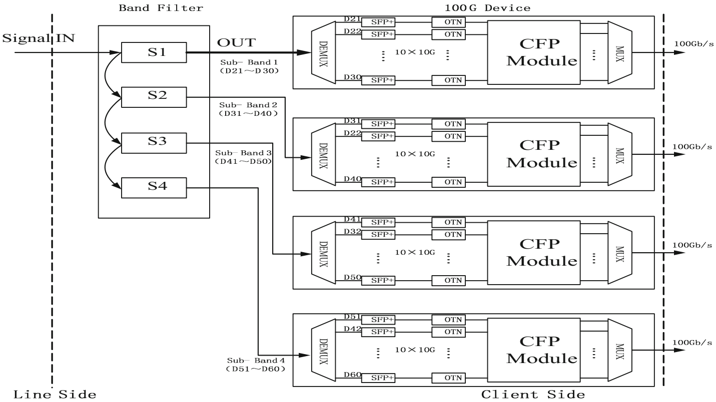


Fig. 8. Block diagram of optical wavelength stack

3.3 Experiment Results of Stack Application

Next, we test the performance of 100G system. The major parameters are receiver sensitivity and dispersion penalty, which represent system performance. Figure 9(a) uses 20 dB attenuator while (b) uses 80 km SM fiber. We can get receiver power by adjusting the variable attenuator. The BER (Bit Error Rate) polylines against to the receiver power are shown in Fig. 10. The total receiving power (receiver sensitivity) of Fig. 10(a) and (b) is about −15.76 dBm and −13.51 dBm respectively around the BER at 10^{-12}. We can see that the receiver sensitivity increases with 80 km SM fiber because of the transmission performance degradation caused by the fiber dispersion. The dispersion penalty is about 2.3 dB.

Based on the 100G BER tests above, we further test function of multiple 100G system according to stacking experiment set up shown in Fig. 2. We use a

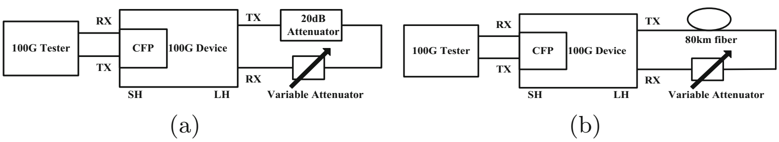


Fig. 9. (a) Line side test diagram with 20 dB attenuator; (b) Line side test diagram with 80 km fiber

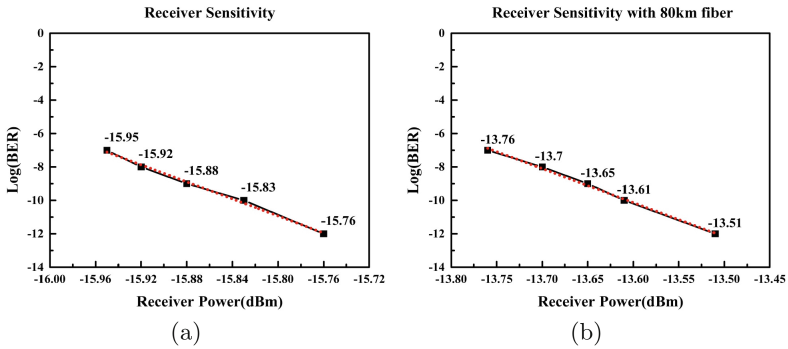


Fig. 10. (a) LH receiver sensitivity with 20 dB attenuator; (b) LH receiver sensitivity with 80 km SM fiber

PC to manage multiple shelfs in the system and monitor them through console. NC can control and configure all SC devices via CLI (Command Line) of software. Moreover, console of NC show the status data of SC. The test results are presented in following Figs. 11, 12 and 13 respectively.

Fig. 11. (a) NC starting up test; (b) SC sync process with NC; (c) SC starting up test; (d) Image synchronization

Figure 11(a), (b) and (c) show NC and SC starting up process and SC sync process with NC. NC will synchronize its DB (Data Base) and RTC (Real Time Clock) information to SC when NC starts up. Figure 11(d) presents SC image upgrading process when we download a new version to NC. It clearly indicates that SC is always under the control of NC.

Figure 12(a) and (b) show shelf status of NC and SC. Figure 12(c) show the real-time display of SC by NC. The status of SC is the same as which we get from NC. This proves that NC can monitor all shelfs status in stacking system.

Figure 13(a), (b) and (c) illustrate the configuration sync process from NC to SC. NC configures long haul admin of SC into disabled status, we can see the

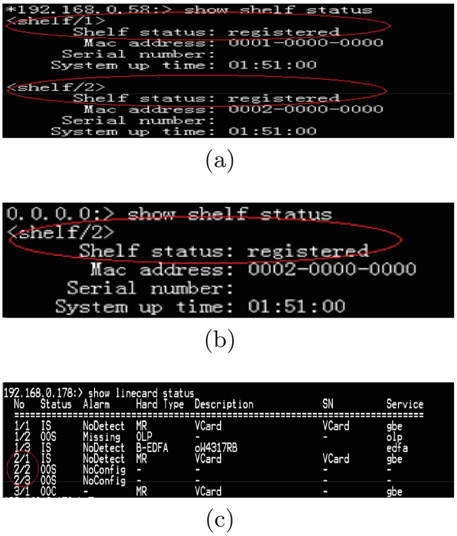


Fig. 12. (a) Shelf status of NC; (b) Shelf status of SC; (c) Linecard status of NC and SC

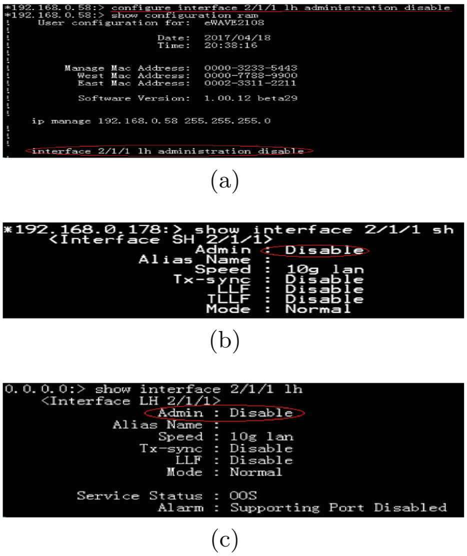


Fig. 13. (a) NC configuring SC process; (b) Configuration result in NC; (c) Effective configuration in SC

successful information in configuration ram of NC, NC also shows the configuration result of SC, and then the command takes effect in SC to make the admin disable, which verifies effective management function of the whole system.

4 Conclusions

In this paper, we have proposed and developed a novel scheme for multiple 100G transmission applications via stacking technology, which is based on our previously proposed low cost and small form factor 100G transmission system [1,4]. The stacking application consists of both network management stacking and optical wavelength stacking. It can support incrementally transmission capacity expansion as well as centralized management of multiple physical devices. The test results show that stacking system for multiple 100G transmissions can operate with stable performance and normal function, at least four 1RU devices can be stacked for 400G optical transmission and with one IP or one NE network management. This technology has a great device cost and size advantage comparing with a large rack equipment, and especially on its advantage with incremental cost/bandwidth addition as well as one IP or one NE with simple management function.

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