Management of a Hub-Spoken Optical Transmission Network with the Point to Multi Point (P2MP) Topology

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Abstract. We have previously proposed and implemented a low cost and small form factor 8x10G optical transmission system based on digital-wrapper technology, which can be used as a Hub node device in the Point to Multi Point (P2MP) or Hub-spoken network application [1]. In this paper, we further develop a small remote edge node device which can complete the full scope work for the Hub-spoken network. Especially, we develop software for the control plane and network management system. This P2MP network management system is based on the fast FPGA processing and the OTN digital wrapper (ITU-T G.709) to provide in-band communication. Our test results show that we can simultaneously do network management from the Hub node to up to 8 remote small edge nodes, which has the great advantage comparing with using multiple OSC (optical supervising channel) of the traditional optical network.

Keywords: Hub-spoken · P2MP · FPGA · OTN digital wrapper

1 Introduction

It is well know that optical network can provide high-capacity, long-distance, high reliable transmission for almost all kinds of different networks for telecom service providers such as metro, access, and long haul. The other applications include enterprise, LAN as well as data center interconnection. In the mean time, optical network has become increasingly complex, so that the importance of the optical network management has also become predominantly necessary, which can ensure efficient, secure, and continuous operation of any network. Specifically, a network management such as OAM implementation should be capable of handling the configuration, fault, performance, security, accounting, and safety in the network [2].

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On the other hand, recently, traditional and new service providers all tend to migrate their role to do not only the network service but also the content providing service. As a result, the demand for Point to Multipoint (P2MP) traffic is quickly increasing due to explosive growth of large amounts of new services such as video content distribution, IP-TV, and other on-demand services. It should be also noted that P2MP application also drives the special requirement in term of network management as it has a typical Hub-spoken traffic pattern or star network topology. To do the optical network management, there are three methods which are (1) digital wrapper technology, (2) subcarrier modulation technology, and (3) optical supervisory channel technology (OSC). Since the sub-carrier modulation technique modulates a low-frequency signal on an existing optical signal, which is essentially increasing the optical channel layer noise to the client signal, and there is also a conflict between the sub-carrier low frequency portion of modulated light and the client signals. On the other hand, OSC is used to transform the management information for point to point transmission application between two NEs (network equipment). However, for P2MP network application multiple OSC should be needed to perform the network management function from HUB to each remote nodes, which will add a lot of cost [3]. In addition, the OSC requires an additional wavelength to transmit the network management information and will be a waste of a wavelength resource. Digital wrapper technology can provide a good optical network concept as it can always combine with standard OTN and FEC (forward error correction), as well as provides the in-band capability for the network management system.

We have previously proposed a small form factor and low cost 8x10G transmission system as Fig. 1. There are 8 channels. Each short haul SFP+ module coverts 10GE traffic to SFI interface. For better performance, 10G OTN framer is applied in system. Each signals can be mapped to 10G OTN framer with FEC by OTN framer and then send to long haul SFP+ for long haul transmission.

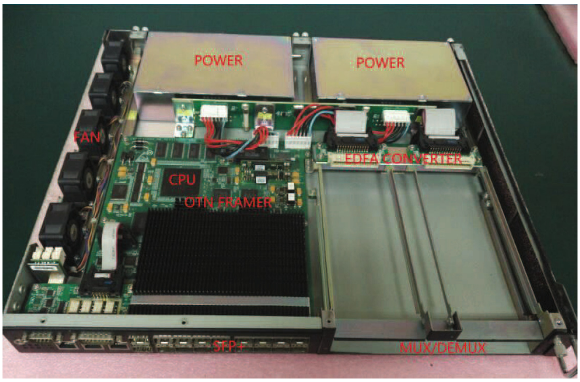


Fig. 1. 8x10G transmission system

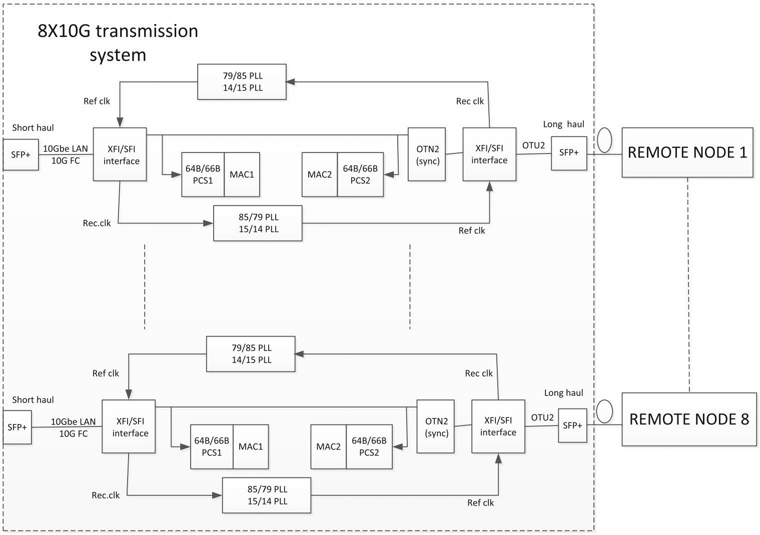


Fig. 2. Hub-spoken network architecture

It can do many flexible network applications, such as point to point WDM transmission or Metro WDM ring application. In addition, the device can also be configured to do the point to multi point (P2MP) application at the Hub node. In this paper, in order to complete the full picture of Hub-spoken network architecture as Fig. 2, we further develop a small remote edge node device which has only 1/4 size of Hub device, and has two slots which can be configured as with one dual-channel 10G card and one management card or both as dual-channel 10G card. In addition, we further do the software development for the control plane and network management system for this P2MP network. It should be noted that we do not use the OSC in optical network, since it will be too much expensive to have 8 OSC links for a Hub to 8 different remote edge nodes. In stead, 2 bytes GCC0 of OTN overhead are used to transparently transport network management message for each in-band communication channel. High speed FPGA is used to insert or drop the overhead to/from the actual OTN frame. The advantage is that at a HUB node up to 8 links OTN overhead can be processed by one FPGA simultaneously. This design has an innovation which can simultaneously do multiple network management, and it can support up to 8 in-band management channels communication from Hub location to 8 different remote nodes through long haul transmission.

The system is based on standard of ITU-T G.709 [4], where the client signal will be encapsulated by a digital wrapper framer. Figure 3 shows the structure of OTN frame, there are many OH (overhead) and it can also provide FEC function which can improve the transmission performance as well as to do the fault monitoring. 2 bytes GCC0 of OTN overhead are used to transparently transport network management message for each in-band communication channel. In our system, high speed FPGA is used to do the overhead insert or drop to/from the actual OTN frame. The rate of the In-band can reach 1.3549 Mbit/s. (OTN frame is 4080 × 4 byte, and the rate of OTU1e is 11.049 Gbit/s, in-band rate is equal to $11.049 * 10^6 * (2/(4080 * 4)) = 1354.9$ bit/s). Hub system can simultaneously access multiple nodes which can provide the network configuration as well as PM and alarm.

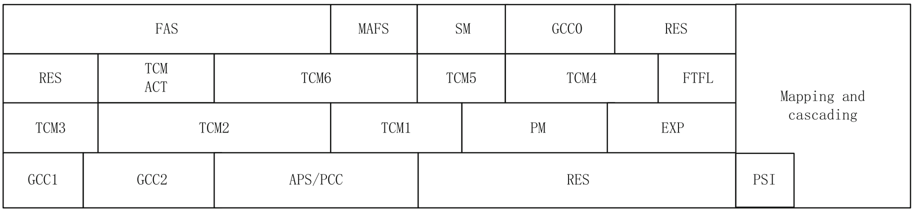


Fig. 3. OTN frame

2 Experiment Set-Up

Figure 4 shows experiment set up for point to multi point or P2MP application. It is a typical structure of HUB-SPOKEN, i.e., a central hub node device is connecting to multiple remote edge nodes. The Hub node usually located at the service provider central office and provided optical connection between their

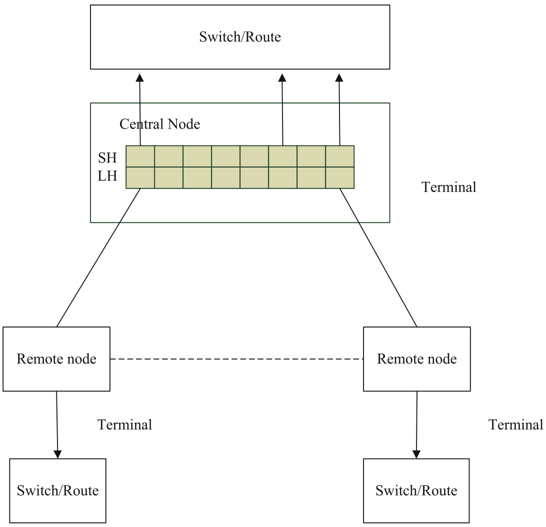


Fig. 4. Star application (central node as terminal)

switch/router and remote edge node. As shown in Fig. 4 up to 8 remote nodes can be supported by this P2MP network.

In addition, remote node can be customer premise, where the original data service is connected to the central node. Our device play the important role to connect the service from Hub node to each remote node, i.e., transmitting traffic from central Hub node to each remote node and also doing some important network OAM management. There is a transmission link between Hub node and each remote node. The details of our hub node transmission device can be referred by reference [1].

The remote edge node device is illustrated by Fig. 5 which is small box with two slots of one management card and one dual-channel 10G card.

Fig. 5. Remote node device

3 OAM SW Implementation

We design a protocol to efficiently transmit the management information transparently, which is responsible to collect and maintain the information about remote node device. 2 bytes GCC0 of OTN OH is used to transparently transport network management information. Frame of In-Band information is listed as the following Fig. 6.

SFD(2byte)	TYP	RES	Length(2byte)	Playload	CRC

Fig. 6. Inband frame

SFD: "0xABAB"; two byte start frame delimiter, which denotes one frame start
TYP: define the type of frame.

"0x01" means networks management package.
"0x02" means remote command for Simple Management use
"0x03" means remote register read and write for register mapping mode
RES: reserved for future use
Length: length of payload to be transmitted. This length is only included the payload.
Payload: Data need to be sent to remote site
CRC: Checksum of even BIP8 check.

In addition, we also develop a private Protocol of LLH (Low Level Shake Hands), which is used to identify the device type include the bit rate and protocol. As an example, if customer put one site device with OTU2(10.709 Gb/s), while the peer site with in OTU1e (11.049 Gb/s). In this case, traffic will not be OK, and in-band OSC channel can also not be built up. Low level shake hands (LLH) protocol is designed to solve this kind of mismatch problem. LLH is implemented by periodically turn on/of long haul laser to generate a low speed optical pules which carries the shake hands information. Frame of LLH: LLH frame is defined as Fig. 7. BYTE1 is LLH sync and LLH Command, BYTE2 is the bit negation of BYTE1 to check if BYTE1 is correct.

SOF0 – SOF2: Start of Frame indicator. "010" means frame start
C/S: Command or Status indicator. "1" C Command; "0" C Status information
D0– D3: Data to transmit.
When D0 = "0", following 3 bit defines the Rate mode of LH
"001" LH Rate is OTU2 (10.709 Gb/s)
"010" LH Rate is OTU1e (11.049 Gb/s)
"011" LH Rate is OTU2e (11.1 Gb/s)
"100" LH Rate is OTU2f
When D0 = "1", following 3 bit defined as other command or information
"0101100" is defined as remote reset command.

SOF0	SOF1	SOF2	C/S	D0	D1	D2	D3

(a) Byte1

/SOF0	/SOF1	/SOF2	/C/S	/D0	/D1	/D2	/D3

(b) Byte2

Fig. 7. LLH frame

4 Remote Node Device

Remote node device is a small and only 1/4 size of hub device which consists of Management card, dual-channel 10G card and power module as show in Fig. 5. Dual-channel 10G card is also show by the Fig. 8, which is constructed by 4

SFP+ module, a digital wrapper chip of VSC8492, FPGA, MCU, RAM, FLASH, etc. Client 10G switch or router sends 10G Signal to SFP+ module. It is then encapsulated into a 10G OTN frame signal by OTN Framer. 10G OTN framer, which is designed to provide FEC function and in-band network OAM management capability. Signal is transparently mapped into 10G OTN frame with FEC. After digital wrapper OTN frame process, signal will be sent to long haul SFP+ module for long distance transmission.

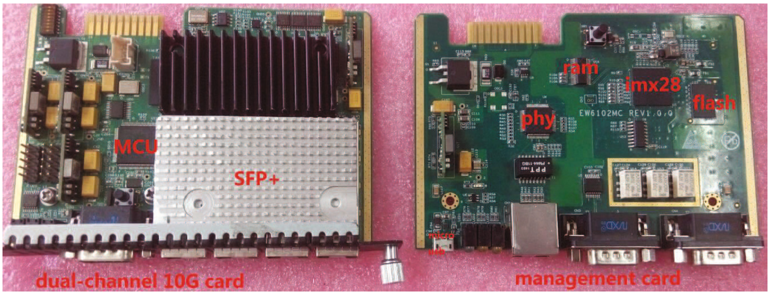


Fig. 8. Management card and dual-channel 10G card for remote device

The software architecture for management card is based on FreeRTOS running on 32 bit-MCU (STM32F103VET6) [5]. The structure of software is shown as Fig. 9 which includes 4 layers. The lowest layer is Hardware layer. The upper layer includes OS software which is designed based the on FreeRTOS (Real-time operating system), software drivers includes Console driver, SFP+ driver, CAN driver, FPGA driver, etc. The second layer including HWM (hardware monitor), DB, alarm, etc. The top of the structure is CLI (command line interface) which receives message including in-band message.

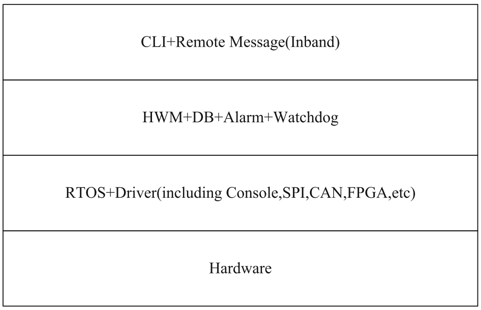


Fig. 9. Software structure based on MCU

After storing information in ping-pong RAM by FPGA, MCU can read the information form buffer through verifying header continually. In order to do priority process with the receiving information. We set a interrupt generated by EXTI and send to MCU. And the Fig. 10 is flow chart about Inband information process.

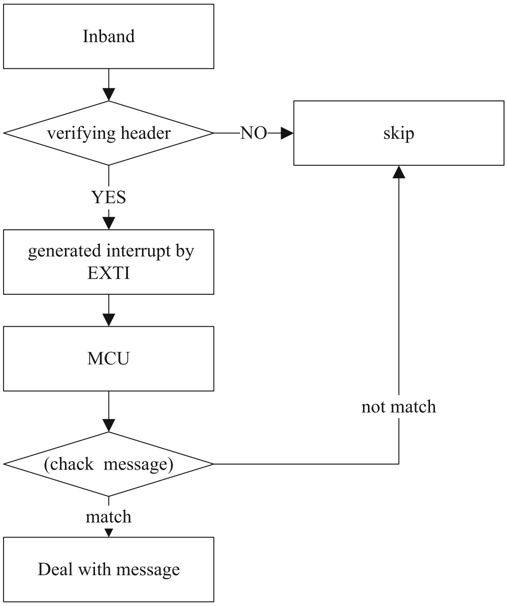


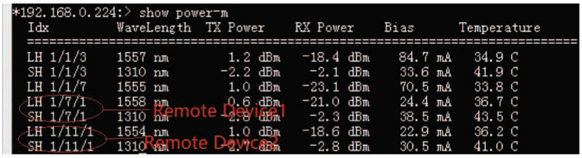
Fig. 10. Flow chart of Inband information process

Management card is designed based on a MCU of control devices which is show by Fig. 8, which can control and manage the management card through CAN bus by UART/USB/LAN interface. It consists of MCU, DDR, FLASH, RAM, etc. In our design, management card can manage the 10G card through LAN/Console/USB and provides the Office alarm functions.

5 Testing Result

P2MP experiment set up is illustrated as Fig. 4. We can use a PC to monitor and manage multi links status from hub to each remote node. All the PM and remote node device status can be monitored by the software from both the hub node location and remote node location. The following Fig. 11 shows the testing results for comparing.

In this experiment, we use console to monitor the device. The Hub equipment can get each remote node equipment status information through digital wrapper in-band management channel. It can be seen that the monitoring status of the remote equipment by hub node is the same as the result which is got directly from the remote node, which proves that P2MP method is implemented correctly and can monitors the multi remote devices efficiently.



(a) local device

(b) remote device1

(c) remote device2

Fig. 11. Local and remote device status

Acknowledgment. We have built an experimental set up for point to multi point (P2MP) optical network by using a low cost 8x10G device of hub node and a small remote node device, which are both developed by ourselves. We also define and develop a software for the control plane and network management system. This P2MP network management system is based on the fast FPGA processing and the OTN digital wrapper (ITU-T G.709) to provide in-band communication. Our test results have shown that we can simultaneously monitor up to 8 remote nodes status from the hub node through the OTN digital wrapper in-band channel, which has the great advantage comparing with using multiple OSC of the traditional optical network.

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