Design and Implementation of Link Loss Forwarding in 100G Optical Transmission System

Zhenzhen Jia[1], Wen He[1], Chaoxiang Shi[1(✉)], Jianxin Chang[2], and Meng Gao[2]

[1] School of Communication and Information Engineering, Chongqing University of Posts and Telecommunications, Chongqing 400065, China
jiazhenzhen343@163.com, wenhcqupt@163.com, shicx@cqupt.edu.cn
[2] CNMP Networks INC., Beijing, China
{jxchang,mgao}@cnmpnetworks.net

Abstract. We have previously proposed and implemented a novel low cost 100G transmission system which has the 1 RU only size and a small form factor [1]. In this paper we further develop a LLF (Link Loss Forward) feature which can monitor the health of this 100G system and make a necessary link failure management. The mechanism is based on the fast FPGA insertion/desertion processing and the usage of un-used overheads of OTN digital wrapper as an in-band tunneling, so that the remote link failure relay, link failure isolation, and alarm report can be done properly. Finally, when the link failure is re-covered, the system will detect it and do automatic recovery as well as alarm clearance accordingly.

Keywords: 100G · Link loss forwarding · FPGA

1 Introduction

Todays communication is entering the data centralized Internet+ era, applications such as cloud computing, mobile internet, 4G/5G wireless, internet video stream, social network and E-commerce, etc., are creating a lot of business opportunities and therefore driving network capacity demand rapidly. The traditional 10G network is facing enormous challenges due to its limited capacity. As a result, large data center switch and router are being upgraded to 100 GbE or 100G OTN interface, which is driving the optical transmission network have be compatible in term of 100G transmission capability [1,2].

On the other hand, Optical network has become increasingly complex, and the importance of the optical network management has also become an increasing predominantly necessary. The presence of a network management system is essential to ensure efficient, secure, and continuous operation of any network. Specifically, a network management implementation should be capable of handling the configuration, fault, performance, security, accounting, and safety in the network [2].

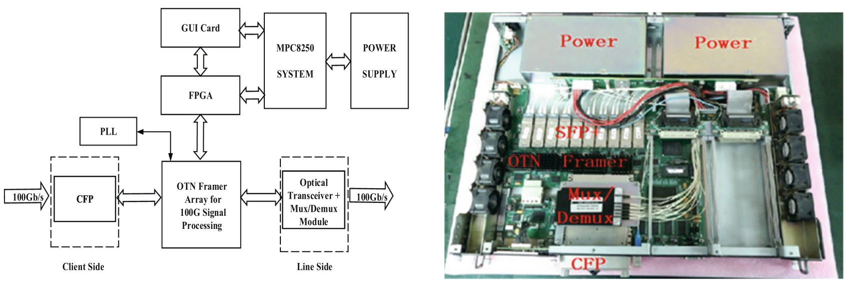
Q. Chen et al. (Eds.): ChinaCom 2016, Part I, LNICST 209, pp. 403–411, 2018.
DOI: 10.1007/978-3-319-66625-9_39

We have proposed and implemented a novel low-cost 100G transmission platform which is based on Inverse-Multiplexing Technology and MLD (Multiplex-lane Distribution) mechanism [1]. In this paper, in order to do necessary link failure and OAM management, we further proposes a scheme to implement the network management feature of link loss forwarding (LLF) [3]. In the 100G transmission system, when there is a sudden link failure occurring on either client side or long haul transmission side, the alarm signal must be delivered to remote equipment instantly, otherwise, the remote equipment will still think the transmission line is in normal situation, and continually transmit data to 100G switch or router, but these data information are really garbage [4]. To solve this problem, we propose to use 2 bytes RES of Optical Transport Network-OTN (the ITU-T G.709 [5]) overhead to transport link loss information. This is implemented by insertion/desertion of link loss message via the high speed FPGA (i.e., Field-Programmable Gate Array), from the on-used overhead of OTN framer. When the link loss message is embedded and transmitted to the remote device together with the 100G real traffic, the receiving alarm signals will make the remote device stop sending the optical signal to its associated 100G switch or router to prevent garbage data or spam.

2 Experiment Setup

2.1 Introduction of 100G Transmission System

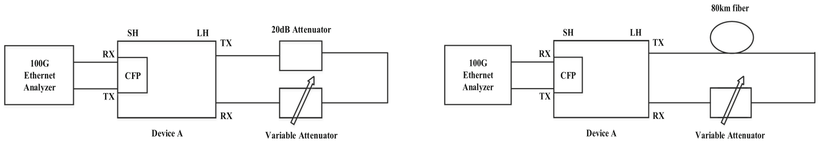
The system block diagram of 100G transmission and the prototype picture are shown in Fig. 1(*a*) and (*b*) respectively. CFP module coverts 100 GE traffic to 10-lane10.3125 Gb/s electrical CAUI interface which is defined by IEEE802.3ba standard [6]. For better performance, ten 10G OTN frames are designed in 100G transmission system to provide FEC and performance function. Every lane of CAUI signal is transparently mapped into 10G OTN frame. And then send to DWDM SFP+ for long haul transmission. In the design, we chose OTN frame



(a) (b)

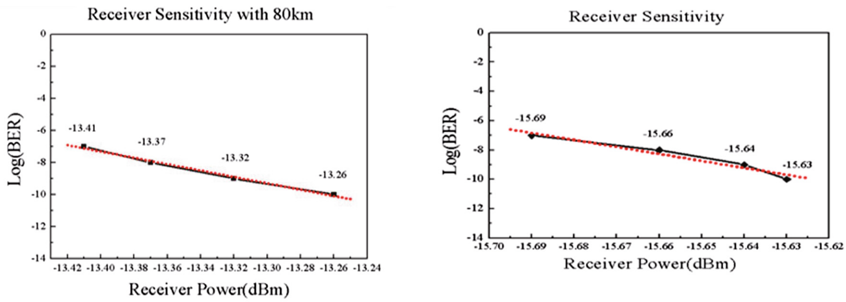
Fig. 1. (a) 100G transmission system block diagram; (b) prototype picture of a 100G optical transmission device

chip to do digital wrapper technology, the MPC8250 is used as a system central controller, and FPGA can insert and drop the link loss signal.



(a) (b)

Fig. 2. (a) Line side test diagram with 20 dB attenuator; (b) Line side test diagram with 80 km fiber



(a) (b)

Fig. 3. (a) LH receiver sensitivity with 20 dB attenuator; (b) LH receiver sensitivity with 80 km SM fiber

The most important parameters of above test in Fig. 2 are receiver sensitivity and dispersion penalty. The difference between Fig. 2(a) and (b) is that (a) uses 20 dB attenuator, (b) uses 80 km SM fiber, which all can get receive optical power through adjusting the variable attenuator. We should note that the receiving power is the total power of 10 lanes. The receiver sensitivity of Fig. 3(a) and (b) is −15.46 dBm and −12.86 dBm respectively around the BER at $10^{-}12$. By comparison, the receiver sensitivity of 80 km SM fiber is bigger because of the system performance degradation which is caused by degradation. The dispersion penalty is about 2.7 dB.

3 Link Loss Forward for 100G Optical Transmission System

3.1 Design of LLF (Link Loss Forward)

In order to transport urgent information between two peer equipment in remote sites, express tunneling is designed by means of RES bytes of OTN frame.

Successive four RES are used as one express package to transmit remote message. The package is defined as Fig. 4.

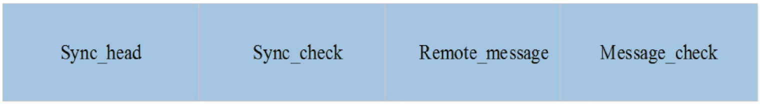


Fig. 4. Urgent LOS frame

Sync_head: Sync_head is used for synchronizing the package between the byte stream.

Sync_check: Sync_check is used to verify that sync head is correct.

Remote_message: Remote_message is a 16 bit data from remote site. Every bit represents different LOS emergency.

Message_check: Message_check is ones complement of remote message. It is used as a checksum.

If these four successive 16 bit RES0 is correctly received, local equipment stored 16 bit Remote_message in internal register.

3.2 Implementation of LLF

As shown in Fig. 5(a) and (b), the system diagram illustrates how the OTN digital wrapper technology is being used.

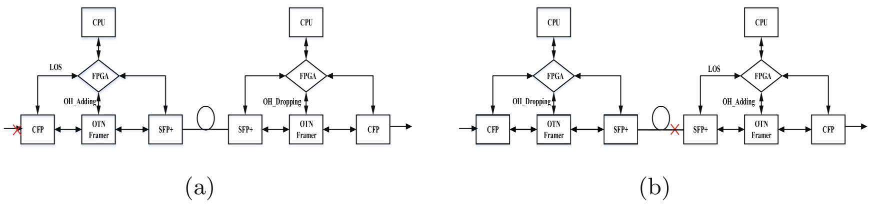


Fig. 5. (a) Processing system block diagram of client side link failure; (b) Processing system block diagram of line side link failure

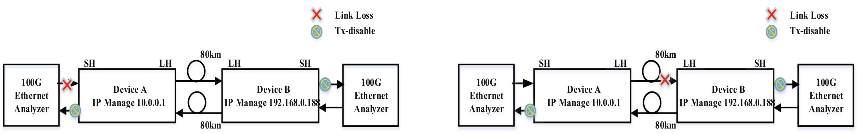
Figure 5(a) and (b) show the implementation principle of link loss forwarding when link failures happen on client side and long haul transmission side, respectively. The main steps to implement link loss forwarding of client side are as follows:

- The link loss occurs at the client side in local device A, or the link loss occurs at the line side in remote device B.

- Let us first look at the local device. The CFP and SFP+ modules have control signal pins which are connected to the FPGA. The CFP module or the SFP+ module detects the loss of signal (LOS) and sends a LOS which represents the link failure of device A or B, once the FPGA get the LOS it will send the signal and transmit in two directions. In the one direction, the local device will receive the LOS and disable the TX of 100G CFP module, so that local device will stop sending garbage data to its connected 100G switch or router to prevent the spam. In the other direction for the remote device, FPGA will insert the LOS signal into the un-used overhead of OTN famer, and then send this link failure message to the remote site device through SFP+ module and long distance transmission.
- On the other hand, the remote side device receives the signal and detects LOS through the received overhead of OTN frame. As a next step, FPGA will process this LOS signal and start the action to disable its client side 100G CFPTX, so that the remote side device 100G CFP will also stop transmitting garbage data to its connected 100G switch or router.
- Based on the above processes, whence link failure occurs at either client side or long link transmission side, both the local device or remote deice will start instant action to disable the 100G CFP TX and cut the connection, so that no more garbage data will continuously be sent to the associated 100G switch or router to prevent the spam. This process is so called link loss forward, or LLF.
- Another scenario is the automatic link recovery process. Once the link becomes normal, FPGA will detect the link status by polling CFP and SFP+ with the 200 ms interval. Once the link LOS disappears, the link recovery to normal signal will be transferred in two directions. In the one direction, local device will turn on the TX and make the 100G CFP working normally; In the other direction, remote device will receive the link normal signal through the express tunneling of OTN framer overhead and also make the 100G CFP working properly.

3.3 Experiment Results of Link Loss Forward

The test results for link loss forwarding have been presented in Fig. 6(*a*) and (*b*) respectively. We can un-plug the RX fiber of CFP or SFP+ modules to produce



(a) (b)

Fig. 6. (a) Link failure test of client side; (b) Link failure test of line side

```
*10.0.0.1:> show power-m
   Idx          WaveLength  TX Power    RX Power    Bias        Temperature
=======================================================================
   LH 1/1/1  -             -           -           -           -
       Lane1  1560 nm       0.6 dBm   -23.8 dBm    88.6 mA    42.3 C
       Lane2  1559 nm       0.7 dBm   -23.4 dBm    96.0 mA    39.1 C
       Lane3  1558 nm       0.8 dBm   -23.0 dBm    97.9 mA    46.1 C
       Lane4  1558 nm       1.0 dBm   -23.6 dBm    86.5 mA    45.4 C
       Lane5  1557 nm       0.8 dBm   -22.3 dBm    80.1 mA    47.4 C
       Lane6  1556 nm       1.4 dBm   -23.1 dBm    93.3 mA    47.8 C
       Lane7  1555 nm       1.1 dBm   -23.3 dBm    91.3 mA    47.4 C
       Lane8  1554 nm       0.8 dBm   -23.7 dBm    82.1 mA    49.2 C
       Lane9  1554 nm       1.4 dBm   -23.1 dBm    91.3 mA    43.6 C
       Lane10 1553 nm       1.6 dBm   -22.4 dBm    95.4 mA    45.8 C
   SH 1/1/1  -             -           -           -           -
       Lane1  -             0.9 dBm    -0.3 dBm    76.7 mA    44.9 C
       Lane2  -             0.6 dBm    -0.5 dBm    76.0 mA    45.0 C
       Lane3  -             0.6 dBm    -0.7 dBm    75.4 mA    44.9 C
       Lane4  -             0.4 dBm    -0.7 dBm    76.5 mA    45.0 C
```

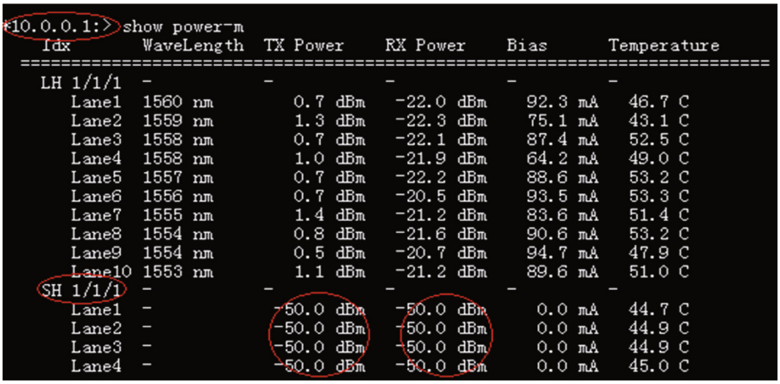
(a)

```
*192.168.0.188:> show power-m
   Idx          WaveLength  TX Power    RX Power    Bias        Temperature
=======================================================================
   LH 1/1/1  -             -           -           -           -
       Lane1  1560 nm       0.7 dBm   -22.4 dBm    92.5 mA    46.5 C
       Lane2  1559 nm       1.3 dBm   -22.5 dBm    75.0 mA    43.0 C
       Lane3  1558 nm       0.7 dBm   -22.4 dBm    87.6 mA    52.2 C
       Lane4  1558 nm       1.0 dBm   -22.2 dBm    64.3 mA    49.0 C
       Lane5  1557 nm       0.7 dBm   -22.7 dBm    88.5 mA    53.0 C
       Lane6  1556 nm       0.7 dBm   -20.7 dBm    93.4 mA    53.2 C
       Lane7  1555 nm       1.4 dBm   -21.4 dBm    83.6 mA    51.2 C
       Lane8  1554 nm       0.8 dBm   -21.8 dBm    90.5 mA    53.0 C
       Lane9  1554 nm       0.5 dBm   -21.0 dBm    94.7 mA    47.8 C
       Lane10 1553 nm       1.1 dBm   -21.4 dBm    89.7 mA    51.0 C
   SH 1/1/1  -             -           -           -           -
       Lane1  -             1.1 dBm     0.3 dBm    75.6 mA    45.0 C
       Lane2  -             0.6 dBm    -0.6 dBm    76.0 mA    44.9 C
       Lane3  -             0.8 dBm    -0.1 dBm    76.2 mA    44.9 C
       Lane4  -             0.8 dBm    -0.4 dBm    77.5 mA    44.9 C
```

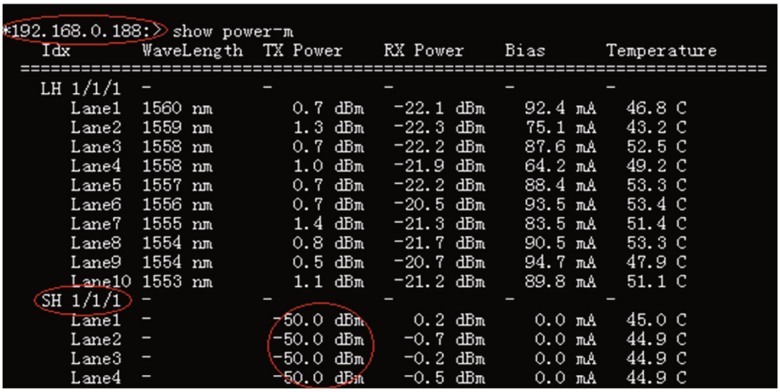
(b)

Fig. 7. (a) The power-m of the device A; (b) The power-m of the device B

the link loss situation, as a consequence TX-disable of 100G CFP modules is our expected result. We do the IP configuration to simulate the connection between the local and remote device. The most important parameters are the power-monitor, whose variation indicates the success of the link loss forwarding. In other words, in the normal working condition, the receiving and transmitting power of optical module are in normal range. On the contrary, when link loss occurs, the receiving power is -50 dBm. Also, when we do the Tx-disable of CFP or SFP+, their transmitting power is -50 dBm, which indicates that there is no light output from CFP or SFP+. On the client side, 100 GbE signal are divided into 4 lanes to be handled. Figure 7(a) and (b) show the power-monitor of device



(a)



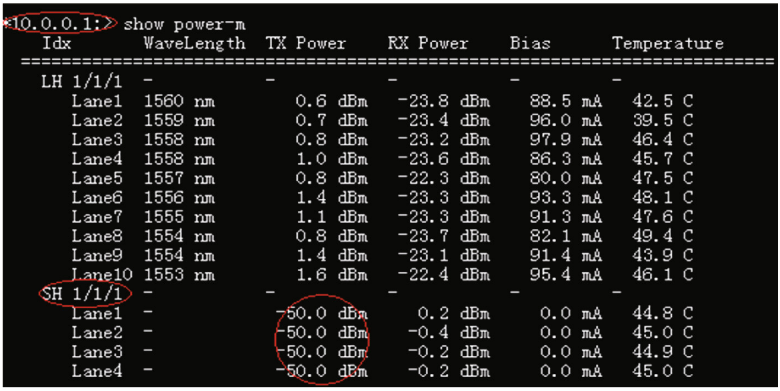
(b)

Fig. 8. (a) The power-m of local devices; (b) The power-m of remote devices

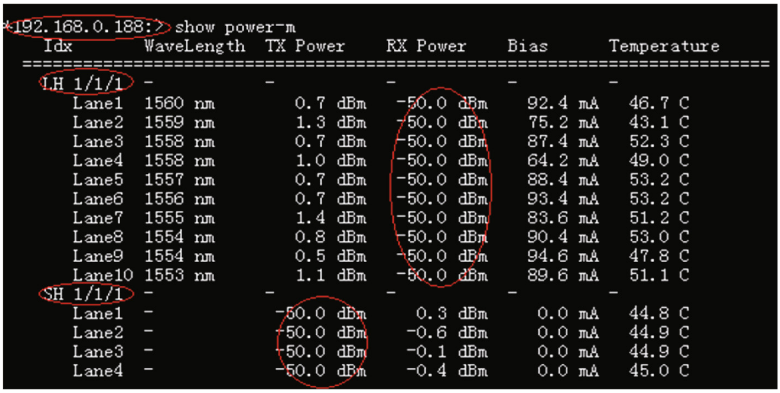
A and B before the link failure. Figure 8(*a*) and (*b*) show the power-monitor of device A and B after the link failure of client side happens . Figure 9(*a*) and (*b*) show the power-monitor of device A and B after the link failure of line side happens . All of the testing data are collected from the network management system via command line or CLI.

In the Fig. 7(*a*) and (*b*), without link failure, the TX and RX power of CFP or SFP+ modules are in normal range, no link failure occurs.

From the Fig. 8, we can know that the RX power of CFP module will change to −50 dBm when the link failure occurs at the client side of device A. At the



(a)



(b)

Fig. 9. (a) The power-m of local devices; (b) The power-m of remote devices

same time, the LOS signal will be transmitted through express tunneling of OTN overhead. After a few seconds, link loss forwarding become effective, as a result the CFP modules of both devices will make the TX disable which shows that the TX power of both devices CFP are −50 dBm, this verifies the effectiveness of client side link loss forwarding.

From the Fig. 9, we can know that the RX power of SFP+ module will change to −50 dBm when the link loss occurs at the line side of device B. At the same time, the LOS signal will be transmitted through express channel by

OTN framer. Thereafter, link loss forwarding starts to action, as a result the CFP modules of both devices will make the TX disable that is the TX power of both devices are -50 dBm, which verify the effectiveness of line side link loss forwarding.

4 Conclusions

Based on our proposed novel low-cost 100G transmission platform, we have further proposed a scheme to implement Link Loss Forwarding-LLF. The mechanism is based on the fast FPGA processing and the usage of un-used overheads of OTN digital wrapper. Our testing results show that when link failures occur, our system can do accordingly link failure management and stopping send garbage data to the connected 100G switch or router to prevent the spam. When the link failure is re-covered, the system will do automatic recovery and return to the good working condition.

References

1. Yang, O., Dong, C., Liu, Q.C., Shi, C.X.: A small form factor and low cost 100 Gb/s optical transmission system based on inver-multiplexing technology. In: International Conference on Communications and Networking in China, pp. 85–89. IEEE (2015)
2. Shi, H.W., Zhang, P.T.: Advanced Technologies for 100G Optical Networking. In: Applied Mechanics and Materials, pp. 303–306 (2013)
3. Miller, G.M., Corp, D.O.: System and method for enhancement of Ethernet link loss forwarding. In: US, US 8687504 B2 (2014)
4. Zhang, X., Xu, J., Liu, W., et al.: The application scheme of 40G and 100G ethernet. In: International Conference on Optical Communications and Networks, p. 41 (2011)
5. ITU-T Recommendation G.709, Interface for the Optical Transport Networks (2009)
6. Fu, K., Ma, Z.Q., Li, X.S.: Standard research of IEEE P802.3ba in 40 Gb/s,100 Gb/sEthernet. Opt. Commun. Technol. **33**, 11 (2009)