Hardware Design Implementation of Transponder/Muxponder in 80 Channel DWDM System

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Abstract- The most up-to-date word in telecommunications technology is Dense Wavelength Division Multiplexing. Dense wavelength division multiplexing (DWDM) is a technology that allocates to the operators of an optical network particular wavelengths or "colors" and mixes them in a sole strand of fiber. Dissimilar data is transmitted concurrently through lanes of light, which are de-multiplexed at the reception end and conveyed to the clients. Instead of installing more fibers or increasing the data transfer rate, the bandwidth of an optical link is ascendable by adding more wavelengths to the system. DWDM has been pioneered for applications in long-haul telecom networks, requiring bulky, sophisticated, and custom instrumentations. One essential component of DWDM system is Muxponder/ Transponder module. The persistence of this paper is to refer to the hardware proposal enactment of the Muxponder/Transponder segment for 80 channel DWDM system functioning at distinct wavelengths in the C-band(1530nm-1565nm) centered around 193.1 THz frequency as per ITU-T Rec.G.694.1 grid, at 50 GHz channel spacing. The system shall support a combination of client interfaces –STM-16, STM-64, Gigabit Ethernet (as per IEEE 802.3 and 802.3ah) and 10G Ethernet LAN and WAN PHY as per IEEE 802.3ae.The DWDM system shall also be capable to interface G.709 based OTN client signal such as OTU-1 and OTU-2.

Index Terms- DWDM, LASER, Optical Fiber, Optical Signal Processing, SDH, SONET, Transponder.

I. Introduction

Due to growing demand of bandwidth ravening application dense wavelength-division multiplexing (DWDM) systems [1]-[6] is one of the promising technology in optical fiber communication. Transponder functions as a crucial component in DWDM system by converting the operating wavelength of the incoming bit stream to an ITU-compliant wavelength .It is an optical-electrical-optical (O-E-O) wavelength converter. There is a big evolution of transponder from 1R to 3R where R stands for retransmission.1R does not adapt any methods to smarten the signal. In 2R, signal is retransmitted after little bit cleaning up of incoming signal .2R simply represents re-time and re-transmit. 3R stands for re-time, re-transmit, and re-shape. Strength and degradation of signal is supervised more closely and precisely in this system.

A transponder shall map grey STM-64,10GigE and OTU-2[7] optical clients to a colored DWDM wavelength towards Mux/De-Mux block and vice versa. Muxponder shall multiplex up to four grey channels of STM-16 or four nos. of OTU-1 or up to 8 nos. of Gigabit Ethernet interfaces depending on the Muxponder type over 10G wavelengths to Mux/De-Mux.A simple structure of DWDM system consisting of WDM terminal and Optical Line Amplifier (OLA) terminal is shown in Fig.1.

A DWDM terminal multiplexer [8]-[9] as shown in Fig.2. The wavelength converting transponders receive the input optical signal, convert that signal into the electrical domain, and retransmit the signal using a 1550 nm band laser. The terminal mux also contains an optical multiplexer, which takes the various 1550 nm band signals and places them onto a single fiber. The Optical Supervisory Channel (OSC) is an extra wavelength typically outside the EDFA amplification band (at 1510 nm). The OSC conveys information about the multi-wavelength optical signal as well as distant surroundings at the optical terminal. It is also normally used for remote software upgrades and user (i.e., network operator) .Network Management information. ITU standards suggest that the OSC should utilize an OC-3 signal structure (though some vendors have opted to use 100 megabit Ethernet or another signal format). Unlike the 1550 nm band client signal carrying wavelengths, the OSC is always terminated at inter-mediate amplifier sites, where it receives local information before retransmission. The optical supervisory channel is used for maintenance purposes and is accessed at each ILA. The optical supervisory channel provides transport of Order Wire, two E1 and one Ethernet Data (user proprietary) NMS data.

A DWDM terminal DE-Multiplexer[8]-[9] as shown in Fig.3 breaks the multi-wavelength signal back into individual signals and outputs them on separate fibers for client-layer systems (such as SONET/SDH) to detect.

In most viable system transponders support bi-directional interface. Here bidirectional specifies both internal side and external side or client side. This is possible when the functionality of output transponder has been assimilated inside the input transponder. According to the ITU-T G.703 standard, in some system, transponder at 40 GHz may perform forward error correction (FEC) through 'digital wrapper' technology [10]-[12].

II. Design Consideration

The Muxponder shall be used to multiplex multiple STM-16 bit rates SDH payloads or multiple GigE interfaces using standards based techniques to form a 10Gb/s colored wavelength to Mux/De-Mux, after carrying out Forward Error Correction(FEC) encoding such as super-FEC specified in ITU-T G.975.1. Optionally, a combo type of Muxponder is also envisaged which shall interface STM-16 as well as GbE interfaces to form 10Gb/s colored wavelength to Mux/ De-Mux, after carrying out Forward Error Correction (FEC) encoding such as super-FEC specified in ITU-T G.975.1 The Muxponder shall be used at TX as well as RX end and shall be interfacing the Mux/ De-Mux component of DWDM equipment. Three types of Muxponder can be considered. For fast provisioning of transparent end-to-end services and spares parts reduction, Muxponder shall be provided with tunable lasers for the DWDM line interface covering the complete C-Band i.e.,80 discrete wavelengths at 50 GHz spacing. On the client side, it is envisaged that all the client optics shall be of pluggable type (through SFPs) [13]-[14] for easy in-service upgrades & maintenance ease. There are three kind of transponder.

A. Type-I SDH 10G Muxponder

The client side of this type of Muxponder shall accommodate 4x STM-16 interfaces. This type of Muxponder shall map up to 4 nos. of optical client STM-16 streams individually into OPU-1/ODU-1 frame format, which are subsequently multiplexed into OTU-2 frame format and transported via a 10G optical wavelength in the DWDM grid as per ITU-T Rec.G.694.1.

In the receive side, OTU-2 data carrying STM-16 payloads shall be converted to electrical signal, after processing for error correction as per algorithms of FEC state machine specified in ITU-T Rec.G.975.1 and de-mapping the overheads and other data of OTU-2, the payload data shall be de-multiplexed into 4 streams of OPU-1 and then to SDH payload at STM-16 bit rate with optical interfaces as per ITU-T Rec.G.957 and shall be presented back to the client interfaces. It is a 3R transponder. Interface diagram of type-I is shown in fig.4.

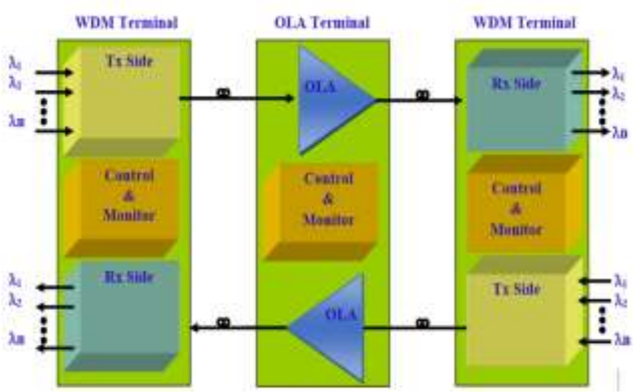


***Fig. 1**. DWDM system block diagram*

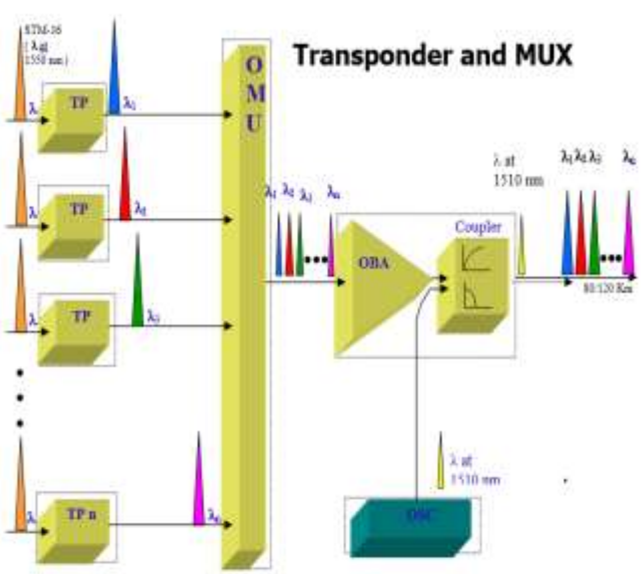


***Fig. 2**. Transponder block diagram with MUX*

B. Type-II 10G Ethernet Muxponder

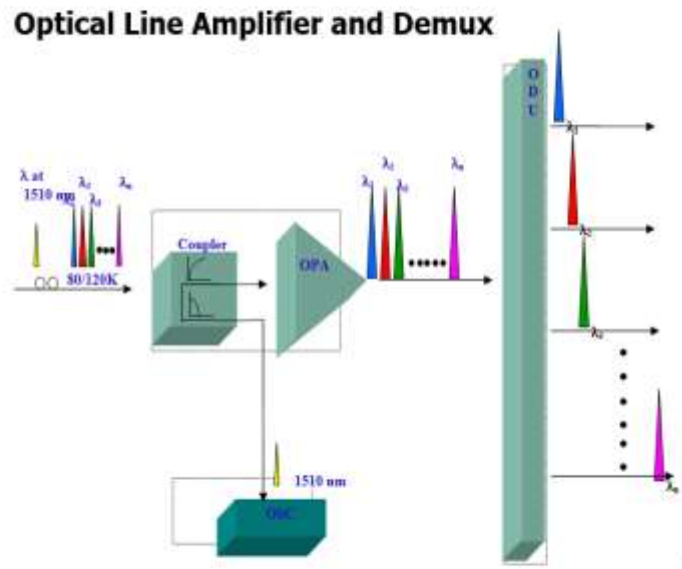


***Fig. 3**. Transponder block diagram with DeMUX*

The client side of this type of Muxponder shall accommodate 8 x GigE interfaces. This type of Muxponder shall map up to 8 nos. (max) of Gigabit Ethernet data into single stream of 10Gpbs.The multiplexing shall be done by adopting standard multiplexing technique to form a standard module such as ODU-2 of ITU-T Rec.G.709.Each Gigabit Ethernet payload data transformed to electrical level shall be grouped into 10 Gbps wavelength. After processing the payload for Forward error Correction (FEC),FEC symbols are mapped onto the OTU-2 payload, as per super FEC algorithm as specified in ITU-T Rec.G.975.1.This combined output after OTU-2mapping as per G.709 is assigned a discrete wavelength in DWDM grid as per ITU-T Recs. G.694.1 to interface a DWDM Mux. In the receive side, OTU-2 signal shall be processed for error correction as per algorithms of FEC state machine specified in ITU-T Rec.G.975.1.The FEC and other overheads are de-mapped from the OUT-2 signal and 10Gpbs equivalent data comprising of 8 nos.(max) GbE payloads shall be presented out to the client interfaces. It is a 3R transponder. Interface diagram of type-II is shown in fig .5

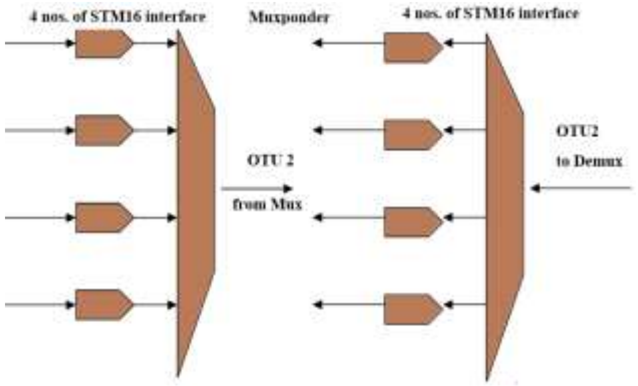


Fig. 4. *TX & RX Muxponder interfaces details-type-I*

C. Type-III SDH and Gigabit Muxponder

This type of Muxponder shall multiplex 2 nos. of STM-16 and 4 nos.of Gigabit Ethernet payloads after GFP mapping to form a single stream of 10Gpbs hierarchical bit rate electrical data as per the multiplexing scheme adopted. The multiplexing shall be done by adopting standard multiplexing technique to form a standard module such as ODU-2 of ITU-T Rec.G.709. After processing the multiplexed in the form of ODU2 for Forward error Correction (FEC), as per super FEC algorithm as specified in ITU-T Rec.G.975.1 and mapping the FEC overhead data onto ODU2,the combined OTU-2 shall be assigned a discrete wavelength in DWDM grid as per ITU-T Recs. G.694.1 wavelength to interface a DWDM Mux equipment. In the receive side, on removal of the FEC data and other overheads from the OTU-2 signal, the resultant 10 Gbps hierarchical data shall be de-mapped to form payload data, having STM-16 and GbE payloads shall be presented out to client interfaces. Interface diagram of type-III is shown in fig .6.

III. HARDWARE DESIGN CONSIDERATION

The hardware for implementing transponder [15]-[29] with different ICs/modules is shown in Fig.7

A. Line side 300-MSA module

A functional block diagram of transceiver module [30] is shown in fig .8.The module are able to cover the data rates 9.95-11.1Gb/s.The transmitter part includes a clock generator and an PLL filter on the transmit reference clock (CG& Filter) and an external reference clock input, a 16:1 multiplexer (MUX) with re-timing, a laser driver and a MZ modulated laser. The output power is controlled via a VOA (Variable Optical Attenuator). The optical output power from the transceiver is monitored through the 5% coupler and PIN diode. The receiver part includes a PIN diode receiver with TIA, AGC-amplifier and limiter, a clock/data recovery circuit (CDR) with an external 167.33 MHz acquisition reference clock input, and a 1:16 de-multiplexer and clock divider. The transceiver is configured with a full C-band or L-Band tunable laser with a Lithium Niobate modulator. The laser can be tuned to any one of the 100GHz channels on the ITU grid that is 192.1THz to 196.0THz for the C-Band. The module is designed for SONET/SDH/10GE applications at 9.953 – 11.1 Gb/s using non-return to zero (NRZ) encoding, in this application we only use it at 10.7Gb/s - OTN. An internal PLL (jitter filter) is provided for the reference clock TXREFCLK. Wavelength tuning is performed through the I2C serial interface. The transceiver has its own micro-controller and EEPROM. The transceiver can be placed in two different mode Pin Control Mode or Soft Control Mode. In Pin Control Mode the transceiver only accepts hardware control commands via hardware pins. In Soft Control mode the transceiver receives commands via the I2C communications interface and ignores the state of all of the hardware control pins (except module reset and laser enable). Soft Control Mode is chosen. Timing and levels of the 16 bit parallel data and clock interfaces complies with [SFI-4] and the pin-out complies with the 300 pin multi source agreement MSA-300.

B. Client side XFP module

On the Client side the transponder uses a hot pluggable serial to serial optical transceiver following the XFP standard. The XFP module is comprised of these blocks:

- A TOSA as the optical transmit section, the TOSA includes the laser, a laser driver etc.
- A ROSA as the optical receive section, the ROSA includes the photodiode TIA etc.
- A transmit data retiming circuit (optional).
- A receive clock and data recovery circuit – CDR.
- A Microprocessor as the controlling element.
- A 2-Wire interface protocol for Management and Diagnostic purposes.

The 10Gbit/s data to and from the XFP connects to FEC+rate adaptor IC. The 10Gbit/s data interface is XFI compliant. XFI is a high speed low voltage (500mVpp) 100 Ω differential AC coupled interface for signals around 10GBit/s.

C. Synchronization

The data processor FEC+rate adaptor must contain four independent clock domains as follows:

- Clock domain for line side receiver
- Clock domain for Client side receiver
- Clock domain for Line side transmitter
- Clock domain for Client side transmitter

The synchronization will be built around the following:
•An 155.52MHz ±20ppm XO oscillator for generating SDH line rate clocks.
•An 161.1328MHz ±20ppm XO oscillator for generating Giga Bit Ethernet clocks.

•Four clock multiplier/jitter attenuating modules are required.
Since the Line side data rate is fixed to 10.71GBit/s, so it needs only one reference clock of 155.52MHz.But since the Client side receiver must be able to receive data rates of 9.953Gbit/s, 10.71GBit/s and 10.31GBit/s it needs a clock signal from both XO's.
The following acquisition clocks are required:
•155.52MHz is supplied for receiving 9.953Gbit/s, i.e. 155.52MHz multiplied with 1
•161.13MHz is supplied for receiving 10.31Gbit/s, i.e. 161.13MHz multiplied with 1
•167.33MHz is supplied for receiving 10.31Gbit/s, i.e. 155.52MHz multiplied with 255/237
Since the data rate on the Client side can be both SDH and Giga Bit Ethernet two reference clocks are needed here.

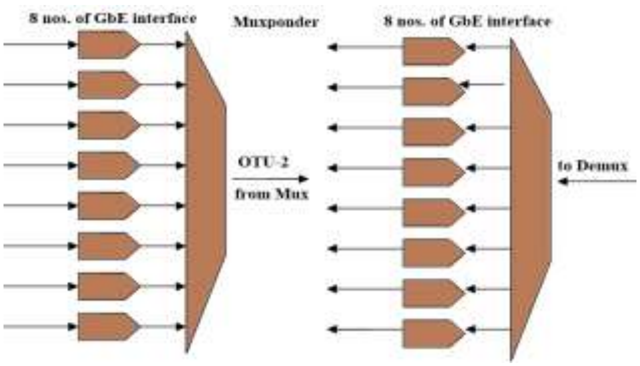


Fig. 5. *TX & RX Muxponder interfaces details-type-II*

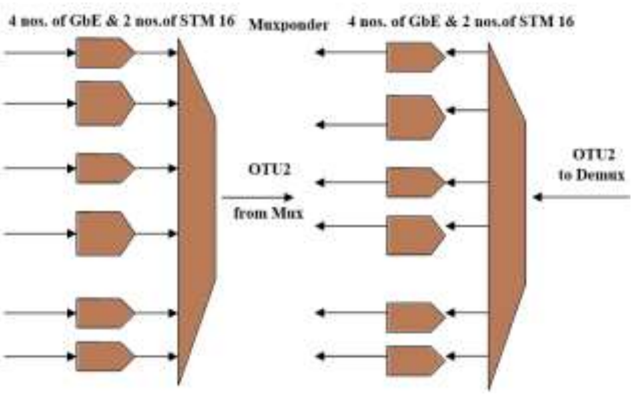


Fig.6. *TX & RX Muxponder interfaces details-type-III*

D. FPGA

In order to be able to monitor and control the data processor and other devices a FPGA shall be used. The following utilities are to be employed:
Concerning data processor:

- Monitoring and control of clock signals - Line Side
- Monitoring and control of clock signal - Client Side
- Monitoring and control of FIFO functions - Line Side

•Monitoring and control of FIFO functions - Client Side
Concerning the XFP module at Client side:

- Monitoring and control of Laser functions
- Monitoring of clock status
- Monitoring of LOPS
- Controlling Reset signal

Concerning the MSA-300 module at Line side:

- Controlling of Laser On/Off function

The following functions can be implemented, i.e. that signals are routed to/from the FPGA:
•Part of the G.709 OH can be Monitored/Inserted for both Line and Client side.
•Drop and insert of GCC channel 0 and 1 for the Line side only.
•G.709 pins for Line and Client side. (LOS, FEC status etc.)
Concerning ECC traffic:
•A dual HDLC Controller is implemented
•Gives access to the Line side ECC channels
•Gives access to the Client side ECC channels

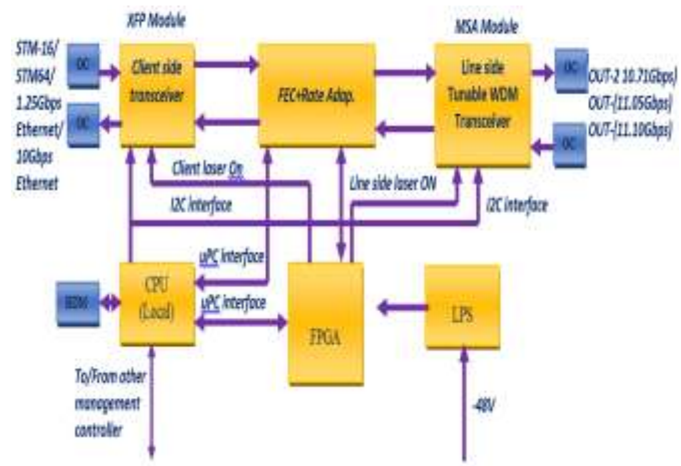


Fig.7. *hardware schematic of transponder*

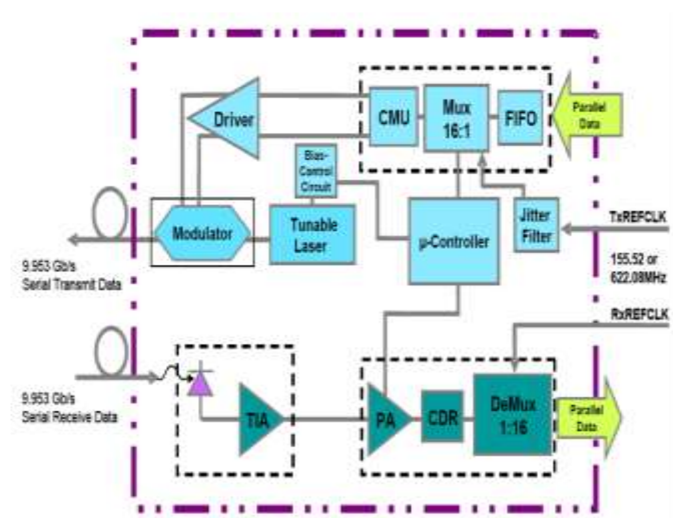


Fig.8. *functional block diagram of transceiver [16]*

E. Forward Error Correction (FEC)

The Forward Error Correction (FEC) is a state-of-art technique which shall effectively increase the transmission bit rate, span length and capacity of digital system of single channel/multi-channel system. The FEC encoder adds computed redundant symbols, producing encoded data, which is higher bit-rate data than that of real payload data bit rate. In the receive side, the FEC decoder part of the equipment performs the error correction and extracting the redundant symbols to generate the data that was encoded by the encoder. The equipment shall support super-FEC as per ITU-T G.975.1, which has been recommended by ITU-T for terrestrial and submarine DWDM equipments.The super-FEC gives higher performance compared to other schemes of ITU-T and uses two FEC codes to achieve higher coding gain. The equipment is expected to give 8 to 8.5 dB net coding gain over and above a 10-12 output BER or better. The equipment shall provide FEC enable/disable capability through LCT/EMS.

F. Local Power Supply (LPS)

For all IC/modules are power up from local power supply i.e. -48V to 5V, 3.3V etc. A synchronous fly back converter. [31] including the LT3825 can be cast-off for local power supply. This circuit has been considered precisely to attain a high current, low ripple, synchronously rectified fly back to efficiently power 3.3V loads at up to 12A from a typical telecom input voltage range 36V-72V.

G. Loop Back Mode

Fig.10. (a)-(d) show the four main Loopback modes that are possible with the 10G Transponder. Although, most of these loopbacks are only accessible during testing and are not visible from the management system. In Loopback mode (Near or Far End) the Line side transmitter is always locked to the Line side Receiver and likewise for the Client side, the Client transmitter is locked to the Client Receiver.

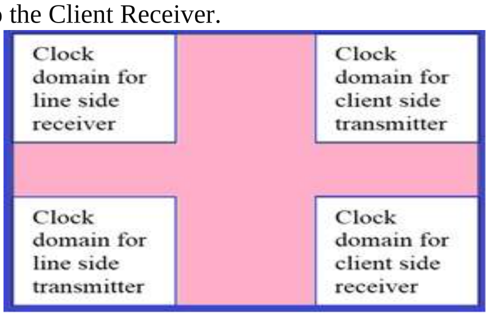
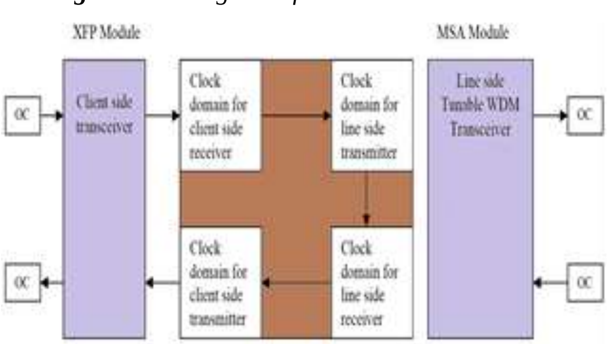
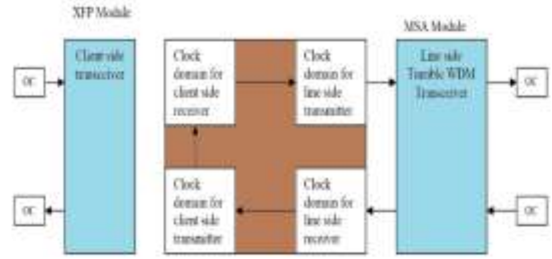


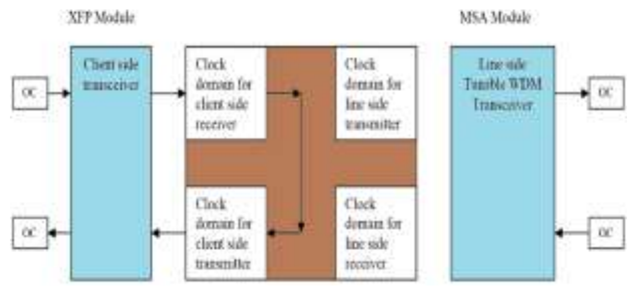
Fig.9.*Block diagram of clock domain*



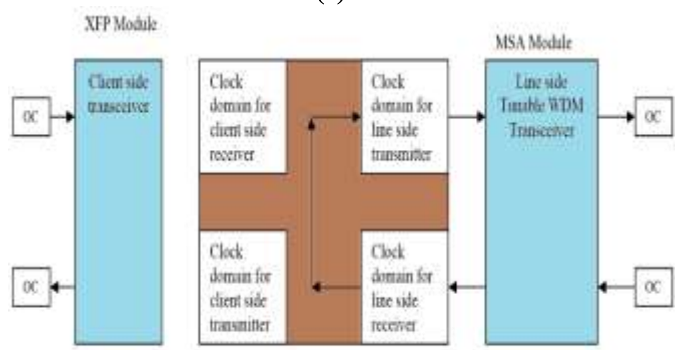
(a)



(b)



(c)



(d)

Fig.10 *.(a) Client Side "Far End" - Loopback Mode,(b) Client Side "Near End" - Loopback Mode,(c) Line Side "Far End" - Loopback Mode(d) Line Side "Near End" - Loopback Mode*

H. Supervisory Parameters

The supervisory system [32]-[33] of the equipment shall be capable of local and remote monitoring the following of the local and remote equipment.

a. Input power of the Transponder.
b. Output power of the Transponder.
c. Laser temperature of the Transponder.
d. Input power of the individual optical channel.
e. B-1 Errors of individual Transponder/Mux-ponder.
f. Bit error ratio (BER) before FEC at OUT-2 line interface of the Transponder/Mux-ponder.
g. Core header errors for GbE/10 GE for Ethernet data.
h. Extension Header errors for GbE/10 GE for Ethernet data.

IV. CONCLUSION

Dense wavelength-division multiplexing, as a domineering technology in fiber optical system, is ultimate for fiber optical based solutions. By translating the functional wavelength of the arriving bit stream to an ITU-compliant wavelength, wavelength-converting transponder serves as a key component in DWDM system. In this paper, a compact design of transponder card in DWDM system has been described with reliable configuration of some desired supervisory parameters its contemporary advancements. For 80 channel DWDM system, 80 number .of transponder cards are required for long haul communication. It is bench-marked that DWDM has updated pioneering optical communication networks. Transponder card is oxygen to the architecture design of the DWDM system. From transmitter end to receiver end, the magnitude and quality of entire optical signal range must be consistent. Amplifiers based on optical design improves the domain of DWDM structures by disregarding losses by spreading of attenuation.

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