Highly reliable 40GbE extender based on OTL3.4 parallel transmission with 1.3μm CWDM and EFEC technologies

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Abstract: We propose a highly reliable 40GbE extender based on OTL3.4 parallel transmission with 1.3μm CWDM and EFEC technologies. Error free transmission of a 40GbE signal over 50km SMF is successfully demonstrated.
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1. Introduction

Driven by high definition video and the penetration of high-speed broadband access, the rising amount of consumer IP traffic is bolstering the overall IP growth rate, e.g. the IP traffic in Japan nearly tripled from 2005 (424.5Gbit/s) to 2009 (1362.9Gbit/s) [1]. Especially large amounts of Internet IP traffic are concentrating at Internet service providers (ISPs), Internet exchange points (IXPs), and data centers (DCs). A low cost interface that can handle bandwidths greater than 10Gbit/s is required for Layer 2 or Layer 3 switches for use in ISPs, IXPs, and DCs.

IEEE 802.3ba, which specifies 40 and 100Gbit/s Ethernet (40/100GbE), was ratified in June, 2010 [2]. 40GbE is the next generation high-speed interface for server and storage applications, and 100GbE is for network aggregation applications. While the maximum transmission distance of the 40GbE standard is 10km, that of 100GbE is 40km. In near term data transport applications, however, demands for 40GbE signal transmission distances in excess of 10km will emerge, and solutions to satisfy the demands are needed.

We proposed 1024B/1027B transcoding to accommodate the 40GbE signal into the OTU3 (Optical Channel Transport Unit 3) payload by bit-rate compression; code-word and timing transparencies were retained [3,4]. This transcoding scheme was adopted in ITU-T G.709 (12/2009) [5]. Furthermore, we have pointed out the frame synchronization issue the optical channel transport lane (OTL) transmission is used under some bit error conditions [6]. The modified frame synchronization scheme for OTL3.4 was adopted in ITU-T G.798 (to be published in 2010).

In this paper, we propose a highly reliable and cost effective 40GbE extender based on OTL3.4 parallel transmission with 1.3 μm coarse WDM (CWDM) directly modulated optics, using wavelengths compatible with 40GBASE-LR4, in conjunction with enhanced forward error correction (EFEC) technologies. The feasibility of the proposed 40GbE extender is confirmed by transmission over 50km of G.652 single mode fiber (SMF). The jitter performance with generic mapping procedure (GMP) mapping and de-mapping is also investigated.

2. 40GbE extender configuration

Figures 1 shows the experimental setup for the proposed 40GbE extender. Optical signals output by a 40GbE analyzer are detected by 4 channel O/E converters. The optical interface between the 40GbE analyzer and O/E converter is 40GBASE-SR4. The O/E converted 40GbE signal is input into a physical coding sub-layer (PCS) processing block. In this block, after 64B/66B block synchronization on each lane, lane recognition, lane reallocation, and lane de-skew are done by using virtual lane markers. 64B/66B block coding was then terminated. In the 1024B/1027B transcoding processing block, the bit rate of the 40GbE signal is compressed from 41.25Gbit/s to 40.117Gbit/s. The transcoded 40GbE signal is input into the GMP processing block. Since the payload capacity of optical channel payload unit 3 (OPU3) is 40.149Gbit/s, the 1024B/1027B transcoded 40GbE signal is mapped into the OPU3 payload with GMP, in which, stuff bytes are inserted according with the OPU3 payload and transcoded at the 40GbE signal bit rate. In the EFEC processing block, optical channel data unit 3(ODU3)/OTU3 over-head information is inserted, and then 7%-EFEC coding is performed yielding the final output of OTU3V frames. The net coding gain of this EFEC is 7.8dB at the BER of 10^{-12} [7]. In the OTL3.4 processing block, OTU3V signals are converted into OTL3.4 signals. The OTU3V frames are inversely multiplexed over physical/logical lanes on a 16-byte boundary aligned with the OTU3V frame that is divided into 1020 groups of 16-bytes. Each 16-bytes of an OTU3V frame is distributed, round robin style, to each of the four physical lanes. On each OTU3V frame boundary, the lane assignments are rotated. Lane rotation and assignment are determined by the two least-significant-bit (LSB) of the multi-frame alignment signal (MFAS) byte. The resulting OTL3.4 signal is E/O converted using SFP+ transceivers. The wavelengths of the four channel SFP+ transceivers are 1271, 1291, 1311, and 1331nm, which are compatible with those of defined in the 40GBASE-LR4 standard. The multiplexed output optical signals with CWDM MUX filter are input into a 50km transmission fiber. After 50km transmission, CWDM signals are de-multiplexed with the CWDM DEMUX filter, and O/E converted. Reverse processing such as OTU3V frame recovery from OTL3.4 signal, GMP de-mapping, 1024B/1027B trans-decoding, and 64B/66B block coded 40GbE frame recovery, is done yielding the final output of the 40GBASE-SR4 signal.

The proposed 40GbE extender is designed for the minimum link budget of 16 dB, because of the following component specifications. The minimum output optical power of each SFP+ transceiver is +1dBm, and the maximum sensitivity of the SFP+ transceiver is -15dBm for BER under 10^{-12}. The CWDM MUX and DEMUX filters both have insertion losses of 2dB. From the back-to-back bit error rate curve, the path penalty of 4dB is compensated by the EFEC coding gain. The designed loss budget of 16 dB supports the transmission fiber length of 40km. Moreover, since the optical transmitters and receivers are normal 1.3 μm uncooled directly modulated laser diodes and normal PIN photo-detectors for 1.3 μm CWDM, the 40GbE extender can be realized cost effectively unlike conventional serial transmission type 40Gbit/s extenders which use optical amplifiers and optical dispersion compensators. Furthermore, since OTL3.4 is used as a parallel transmission interface, carrier-class highly reliable operation, administration and maintenance functions can be realized by using the overhead information of OTU3V/ODU3.

3. Transmission experiment

We evaluate the transmission performance over 50km of SMF. Figures 2 (a) and (b) show the input and output spectra of the 50km transmission fiber, respectively. The differences in the output powers from four transmitters after passing through the CWDM MUX filter was less than 1dB. The received power difference at the transmission output was about 3.6dB, this was due to the wavelength dependence of G.652 SMF loss. The loss of the transmission fiber was 20.2dB @1271nm. Figures 3 (a) and (b) show the error count of 40GbE signals measured at the 40GbE analyzer without and with EFEC coding, respectively. The MAC frames were 64 bytes long. Figure 3(b) confirms the bit error free transmission of the 40GbE signal over the 50km SMF with EFEC coding over periods of 30 minutes. We used an optical attenuator to confirm that the allowable link budget of this extender was 21.5dB. This indicates a component specification margin of 5.5 dB.

4. Jitter performance by the GMP mapping and de-mapping

As previously mentioned, accommodating the 1024B/1027B transcoded 40GbE signal into OPU3 payload, involves GMP mapping and de-mapping processing with stuffing and de-stuffing processing. Thus jitter generation in the de-synchronization process is an important evaluation parameter. We measured the jitter generation with the GMP mapping and de-mapping process in output lane #1 by using a 10.3Gbit/s jitter analyzer, see Figure 4. The test signal was a 2^{23}-1 PRBS pattern. At the mapping side, the PCS processing block detected the loss of lane alignment error and generated local fault (LF) signal. At the transcoding processing block, the 64B/66B coded LF signal was transcoded into an 1024B/1027B transcoded LF signal which was then is mapped into an OTU3 frame with GMP mapping. The OTU3 signal was loop-backed at the GMP processing block. The GMP de-mapping processing block regenerated the 1024B/1027B transcoded LF signal from OTU3 frame signal. The 1024B/1027B trans-decoding block regenerated the 64B/66B block coded LF signal from the 1024B/1027B transcoded LF signal. At the PCS transmitting block, the 64B/66B LF signal was converted into a 2^{23}-1 PRBS signal for jitter measurement. The 10.3Gbit/s jitter analyzer detected the 2^{23}-1 PRBS pattern to measure jitter generation. Figure 5 shows the measured jitter generation performance. The solid line shows the wide band jitter (20KHz-80MHz) with GMP mapping and de-mapping. The squares show the jitter generation loop-backed at the PCS processing block without transcoding and GMP processing block, for reference. Figure 5 indicates that GMP mapping and de-mapping did not increase the jitter generation. The result satisfies the jitter generation standard of STM-64 defined in ITU-T G.825.1.

5. Summary

We have successfully demonstrated the 50km transmission of a 40GbE signal using our 40GbE extender based on OTL3.4 parallel transmission with 1.3 μm CWDM direct modulation based optics; the wavelengths used are compatible with 40GBASE-LR4 standard, and EFEC technologies. GMP mapping and de-mapping were confirmed to offer excellent jitter performance.

Acknowledgement

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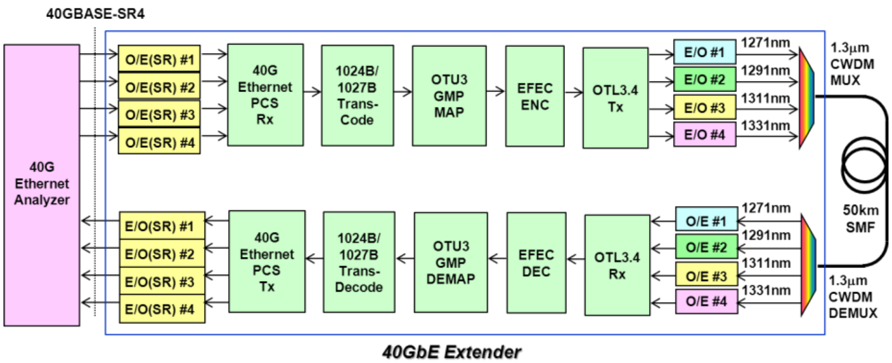


Figure 1 Configuration of 40GbE extender and transmission experimental setup

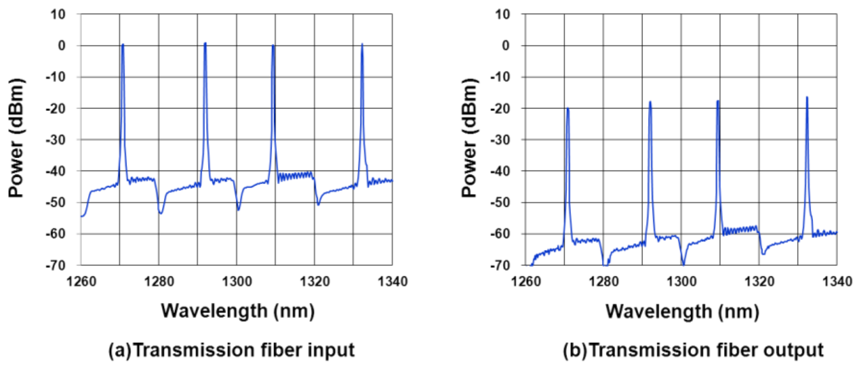
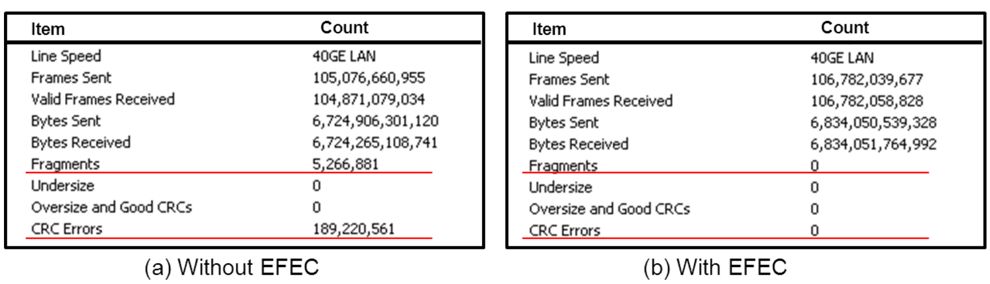


Figure 2 Optical spectra before and after 50km transmission



Item	Count
Line Speed	40GE LAN
Frames Sent	105,076,660,955
Valid Frames Received	104,871,079,034
Bytes Sent	6,724,906,301,120
Bytes Received	6,724,265,108,741
Fragments	5,266,881
Undersize	0
Oversize and Good CRCs	0
CRC Errors	189,220,561

(a) Without EFEC

Item	Count
Line Speed	40GE LAN
Frames Sent	106,782,039,677
Valid Frames Received	106,782,058,828
Bytes Sent	6,834,050,539,328
Bytes Received	6,834,051,764,992
Fragments	0
Undersize	0
Oversize and Good CRCs	0
CRC Errors	0

(b) With EFEC

Figure 3 Screen shots of the 40GbE analyzer

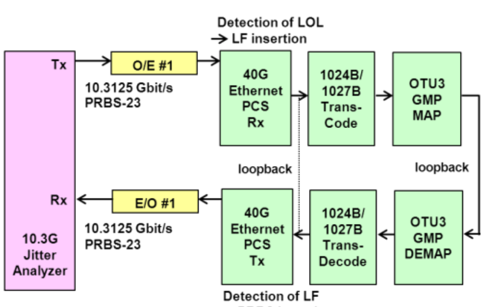


Figure 4 Setup for jitter measurement

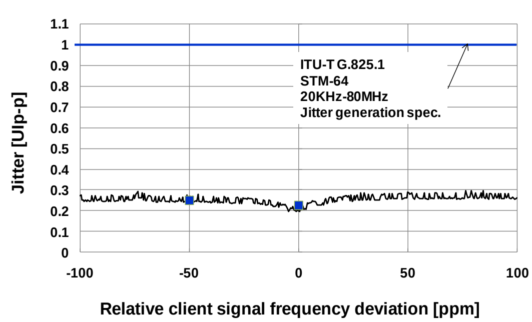


Figure 5 Jitter generation with GMP mapping and de-mapping