Wide-range BER Measurement Scheme by Estimating BER of Discarded Frames for 10 G-EPON Systems

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Abstract:
This paper describes a new BER measurement method obtaining the BER by estimating the number of error bits in discarded frames using the rate of discarded frames. The BER is obtained precisely by the method.
OCIS codes: (060.2330) Fiber optics communication; (060.4510) Optical communication

1. Introduction

In 10G-EPON, the limits of the bit error rate (BER) are defined as 10^{-3} or lower at the physical medium dependent (PMD) service interface and 10^{-12} or lower at the physical sub-layer (PHY) service interface by the IEEE802.3 standard [1]. A robust method of the BER measurement at the PHY service interface for a wide BER range around the specified values is therefore needed for system development. Figure 1 shows a 10 G-EPON system and block diagrams of an optical network unit (ONU) and an optical line terminal (OLT) in an upstream direction. For upstream communication, the ONU applies transmission codes to frames and transmits them as a burst signal. The OLT receives the burst signal and restores the frames from the received signal. On the other hand, the BER is generally obtained by dividing the number of all transmitted bits (N_{all}) into the number of error bits of all transmitted frames (E_{all}) as

$$BER = \frac{E_{all}}{N_{all}}. \quad (1)$$

For 10G-EPON system, the BER has to be measured at the signal after forward error correction (FEC) decoding and physical coding sub-layer (PCS) (descramble, 64B/66B decoding) to obtain the BER at the PHY service interface.

In practical 10G-EPON systems, a frame is discarded at the OLT if the frame contains error bits occurring between the ONU and the OLT. The number of error bits of discarded frames can not be recognized, so the BER is not obtained precisely. To solve this problem, methods that obtain the BER by using the frame error rate (FER) have been proposed [2, 3]. These methods are able to estimate the BER precisely in the low-error-rate region. However, the BER is not obtained precisely when it approaches 10^{-3} or higher. This is because almost all frames contain one or more error bits at this BER and are discarded at the OLT. So the FER becomes 1 at this BER. This means that for system development the BER has to be measured around 10^{-3}, which is not possible with the conventional method.

Even if the OLT can be modified so that frames with error bits are not discarded, some frames that cannot be recognized as frames at the PCS are still discarded. This is because the frames cannot be recognized if a start or a terminate code is corrupted. All frames are not received at the OLT and the correct BER is not obtained. Therefore, a new BER measurement method is needed that obtains BER precisely, even if some frames are discarded.

We propose a new method of BER measurement at the PHY service interface. The method obtains the BER by counting the number of error bits of error frames restored at the OLT and by estimating the number of error bits of discarded frames using the rate of the number of discarded frames to transmitted frames.

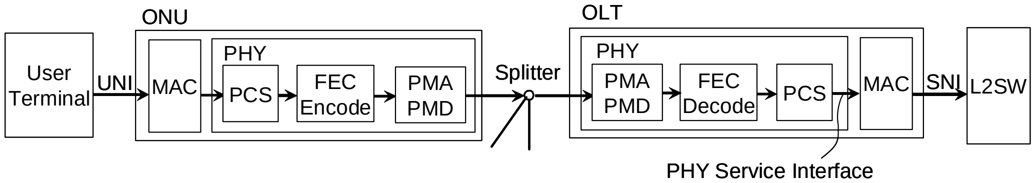

Fig. 1. 10G-EPON system (upstream)

2. BER measurement method

In our method, the BER is obtained by dividing the total number of bits of transmitted frames into the number of error bits of the frames from the ONU. In order to acquire the total number of error bits in both the received and

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discarded frames at the OLT, the method counts the number of error bits of the received error frames and estimates the number of error bits of the discarded frames using the rate of discarded frames.

The BER of all frames at the PHY service interface at the OLT (BER_{total}) is obtained by dividing the total number of bits of transmitted frames from the ONU into the total number of the error bits of the received frames at the OLT:

$$BER_{total} = \frac{E_{out} + E_{los}}{F_{out} N} \ . \qquad (2)$$

The total number of the error bits is the sum of the number of the error bits of the received error frames (E_{out}) and the number of the error bits of the discarded frames (E_{los}) at the OLT. E_{out} is obtained by counting the number of error bits of the error frames received at the OLT. The number of all transmitted bits is obtained by multiplying the number of transmitted frames (F_{out}) by the number of bits in a frame (N). E_{los} cannot be counted, so we propose obtaining E_{los} by estimating the BER of discarded frames (BER_{los}).

E_{los} is obtained by multiplying the number of bits of the discarded frames by the BER of the discarded frames (BER_{los}) as

$$E_{los} = N(F_{out} - F_{in})BER_{los} \ . \qquad (3)$$

In this equation, F_{in} is the number of received frames at the OLT, and the number of bits of the discarded frames is acquired by multiplying N by the number of the discarded frames that are transmitted by the ONU but not received at the OLT (F_{out}-F_{in}).

If one or more bits of a control code, such as a start or a terminate code of the frame, is corrupted, the frame is discarded at the OLT. The proposed method assumes that the rate of discarded frames (R_{los}) is equal to the probability of the corruption of the control codes. R_{los} is thus obtained using the total number of bits of the control codes (n) and BER_{los} as

$$R_{los} = 1-(1- BER_{los})^n. \qquad (4)$$

On the other hand, R_{los} is also expressed by dividing the number of the frames received at the OLT (F_{out}) into the number of the discarded frames (F_{out}-F_{in}) as

$$R_{los} = \frac{F_{out} - F_{in}}{F_{out}} \ . \qquad (5)$$

Finally, BER_{los} can be obtained by eqs. (4) and (5). As described, the proposed method can precisely obtain the BER of all transmitted frames by estimating the number of error bits of the discarded frames using the rate of discarded frames.

3. Result

3.1. Result of simulations

We verified that the proposed method obtains the BER precisely by simulation. We prepared a behavior model of 10 G-EPON and simulated the method and acquired the BER while corrupting bits between the ONU and OLT. The error bits were inserted according to a Poisson distribution that approximates the distribution of the error of the line. Figure 2 shows the simulation result. The graph shows the BER at the PHY service interface versus the BER at the PMD service interface at the OLT. When the BER at the PMD service interface at the OLT is more than about 10^{-3}, the FER becomes 1 because all frames contain one or more error bits. The BER at the PHY service interface obtained by the conventional method also becomes 1 when the FER is equal to 1. In contrast, the proposed method obtains almost the same value as the ideal BER of more than 10^{-3}. The proposed method enables the BER measurement in a wide range, including the BER of over 10^{-3} that is needed for system development.

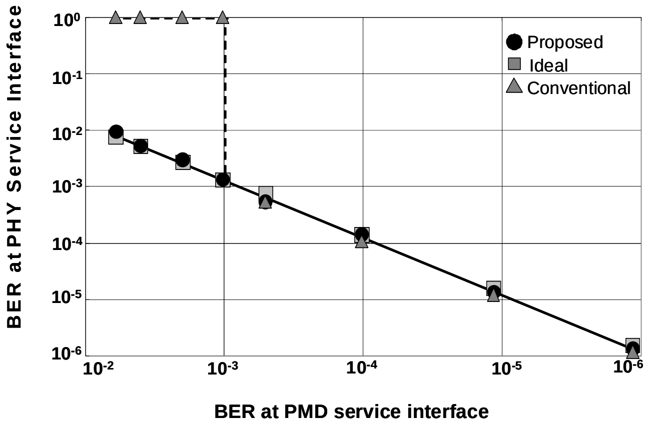

Fig. 2. Simulation results for BER at the PHY service interface.

3.2. Result of examination

To verify that the proposed method can obtain the BER in an actual system, we used it to measure the BER using an evaluation board of the 10 G-EPON system as shown in Fig. 3. Figure 4 shows the results obtained by the proposed method and the conventional one. The frames transmitted from the ONU were supplied by a LAN analyzer. The BER was examined for corrupted bits between the ONU and OLT using attenuator. The frame length was 1000bytes. The number of error bits of error frames received at the OLT was counted by capturing the frames with the LAN analyzer. The BER with conventional method becomes 1 over the BER of 10^{-3}, as in the simulation results. On the other hand, the proposed method provides the BER in a wide range, including the BER of more than 10^{-3}. The proposed BER measurement method can therefore be used for the system development that needs measurement of BER of around 10^{-3}. The BER after FEC decoding was also be measured by our method.

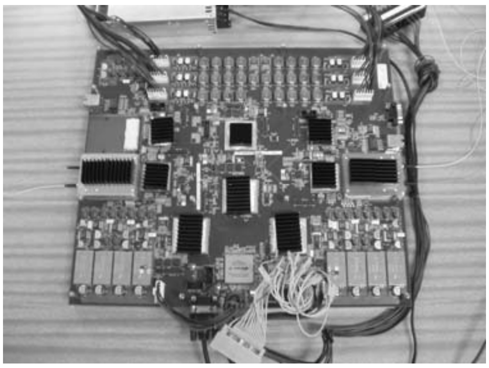

Fig. 3. Evaluation board of 10G-EPON system.

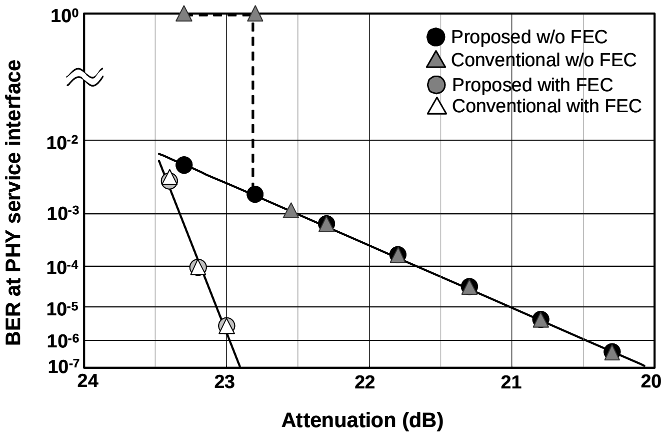

Fig. 4. Result of BER at PHY service interface at 10G-EPON system.

4. Summary

We proposed a new BER measurement method at the PHY service interface for the 10G-EPON system. The method obtains the BER by estimating the number of error bits of the discarded frames using the rate of the discarded frames. With the method, the BER of around 10^{-3} is obtained precisely, which is needed for system development. Therefore, precise BER measurement of an actual 10G-EPON system is achieved, and our method can accelerate the development of a high-speed network of the next generation.

5. References

[1]IEEE Std 802.3av-2009.

[2] ITU-T G.975.

[3] C. Pinart, "Minimum-intrusion approaches for in-service BER estimation in transparent WDM networks", in Proc. 17th IFIP/IEEE International Workshop on Distributed Systems: Operations and Management (DSOM 2006). Dublin (Ireland), October 23-25, 2006.