Fault Monitoring in Passive Optical Networks Using Burst-Mode FBG Optical Sensor

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***Abstract*—This paper presents a fault monitoring method in passive optical networks (PON) using Burst-mode uniform FBG optical sensors. The proposed monitoring method detects physical layer faults between optical line terminal (OLT) and optical network units (ONUs). The FBG interrogation subsystem located in central office (CO) near OLT transmits FBG monitoring signal to every ONU. Each ONU branch contains an FBG sensor subsystem. The proposed system provides Burst mode upstream data transmission using time division multiple access (TDMA). We show that the proposed system is a cost-effective solution that has ability to monitor faults of any ONU branches in PON.**

Keywords—Fault Monitoring in PON; Fiber Bragg Grating; Burst-Mode uniform FBGs.

I. INTRODUCTION

Passive optical network (PON) is a cost-effective next generation access network which has point-to-multipoint (P2MP) architecture and provides upstream data transmission using time division multiple access (TDMA). A PON consists of optical line terminal (OLT) located at central office (CO), multiple optical network units (ONU) and passive optical splitters. PON is possible to provide service for up to 128 users, works at a distance of about 20km [1].

For Ethernet-PON (EPON), OLT will broadcast an Ethernet frame to every ONU in the downstream direction and ONU receives it selectively. In the upstream direction, ONU will transmit upstream data to OLT during the allocated time slot through the TDMA scheme. This is performed by OLT based on the traffic information of ONUs and is called as dynamic bandwidth allocation.

There are several fault monitoring systems in PON which have been presented. For example, the fiber-fault monitoring technique for PON based on fiber Bragg grating (FBG) sensor has been proposed [2-3]. This method can identify faults of ONU branches by using FBG sensors with different central wavelengths.

Another fault monitoring method using optical frequency domain reflectometer (OFDR) and FBG sensors [4]. In this method, the interferometer units (IF units) including an FBG sensor located at the ONUs. This system detects fault of ONU branch by analyzing refection wavelength signal from FBGs.

In this paper, we proposed a fault monitoring system in the PON using uniform FBG optical sensor. By analyzing the Burst-mode reflection signal from FBG sensor placed at ONU that is transmitted in a time slot allocated by OLT. The rest of this paper is organized as follows: In Section II, we introduce the FBG sensor based proposed monitoring system. Section III shows simulation results of the proposed monitoring system in PON. Final conclusions are covered in Section IV.

II. FBG SENSOR BASED MONITORING SYSTEM

A. Fiber Bragg Grating Sensor

Fiber Bragg Grating (FBG) is one of the most popular choices for optical fiber sensors in the PON network monitoring system due to their light reflection function. When a broadband light is transmitted to an FBG, then only the specific wavelength of FBG sensor is reflected return. The central reflected wavelength spectrum of this light is called Bragg's wavelength [5], and is described as follows:

$$\lambda_B = 2n\Lambda \tag{1}$$

where λ_B is the Bragg wavelength, n is the effective refractive index of the fiber core, and Λ is the spacing between the gratings, known as the grating period.

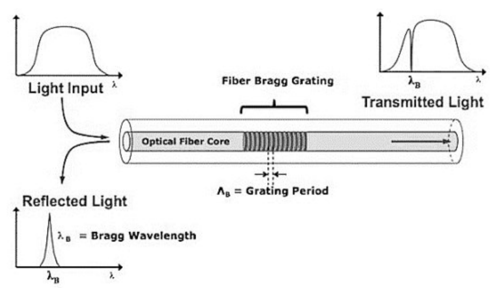

Figure 1. Operation of an FBG Optical Sensor

B. Proposed Monitoring System Structure

In figure 2, this is the proposed monitoring system in PON based on Burst mode uniform FBG optical sensors. The OLT device located in the central office, transmits downstream data at wavelength of 1490 nm and 1550 nm to ONU, and receives upstream data transmitted from ONU with wavelength of 1310 nm. The FBG interrogation unit placed in the central office transmits the monitoring signal at a wavelength of 1650 nm and receives the reflected sensing signal from ONU. The reflection signal of FBG sensor from ONU is transmitted to the optical time domain (OTD) through an optical circulator. WDM (mux/demux) devices are utilized for the wavelength division multiplexing function of the data transmission with wavelength of 1310 nm, 1490 nm, 1550 nm as well as the monitoring signal transmission at wavelength of 1650 nm.

The ONU device placed near end user, receives the downstream data at wavelength of 1490 nm and 1550 nm through the passive optical splitter and transmits the upstream data at wavelength of 1310 nm. In this case, data is transmitted upward in a time slot allocated by the TDMA scheme. This method is called the Burst mode transmission method. After a 1650 nm light source transmitted to FBG sensor unit located in ONU from FBG interrogation unit, each uniform FBG sensor will transmit a reflection signal during a specific time slot allocated by the OLT. By using the Burst mode optical signal transmission method, uniform FBG sensors can be utilized to implement the monitoring function of the time division multiple access method in the PON system. In addition, multiplexing and demultiplexing functions for the upstream and downstream wavelength are performed by the optical wavelength multiplexer placed in the ONU. At CO, the FBG interrogation unit obtains and analyzes the received monitoring signal transmitted from ONU, after detecting the presence or absence of the Burst mode returned signal that represents for each ONU branch. Therefore, we can supervise the faults of any ONU in PON.

III. Simulation

The proposed monitoring system in PON using uniform FBG sensors is simulated by OptiSystem simulation software from Optiwave. In this system, downstream data transmitters located at OLT, and upstream data transmitters located at ONU with the output power is set to 3 dBm. It is assumed that the speed transmission of whole system is 10 Gbps. The monitoring signal source placed at FBG interrogation unit with the output power is set to 3 dBm. Each ONU branch is equipped with an FBG sensor unit which includes a Burst modulator and a uniform FBG sensor with a central wavelength at 1650 nm. The number of ONU is 4 and the time slot allocated for each ONU is fixed by 10 nsec.

In this simulation, we simulated two different cases. In the first case, the FBG monitoring signal transmitted to ONU in the normal condition. The distance between OLT and ONU_1 is 14 km, the distance between OLT and ONU_2 is 16 km, the distance between OLT and ONU_3 is 18 km, the distance between OLT and ONU_4 is 20 km. In the second case, the parameter is set similar to the first case but there is a fault at the ONU_2 branch.

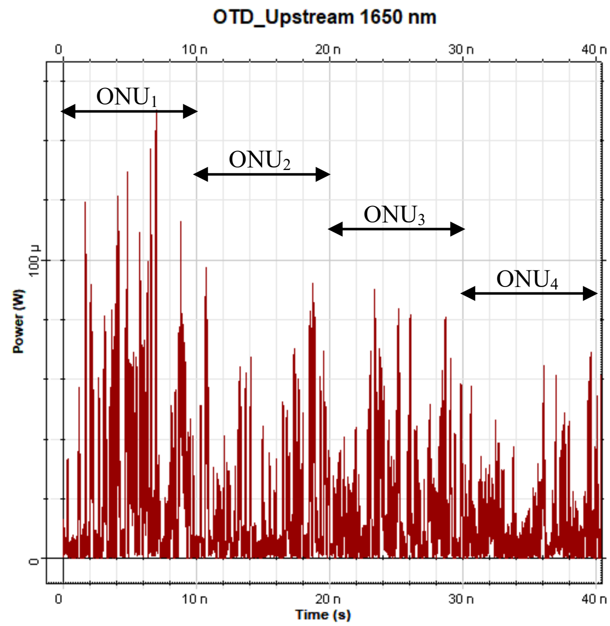

Figure 3. The monitoring signal received by TDM method in the first case with normal condition.

The Burst mode monitoring signal is returned continuously to FBG interrogation unit with a 40 nsec period, each the allocated time slot of 10 nsec corresponds with an ONU branch is monitored. It is easy to see that the intensity of reflection signal pulse decreases due to the distance from OLT to ONU increases, as shown in figure 3.

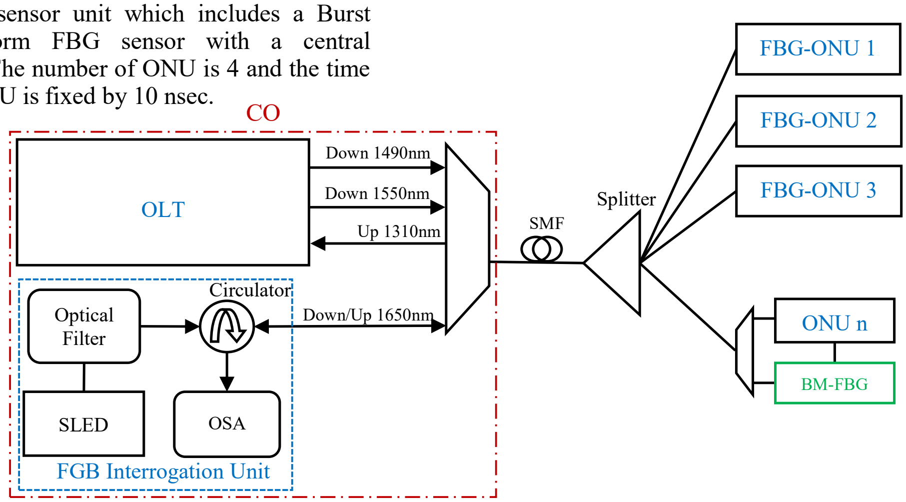

Figure 2. Block diagram of the real-time monitoring in PON using uniform FBG optical sensors

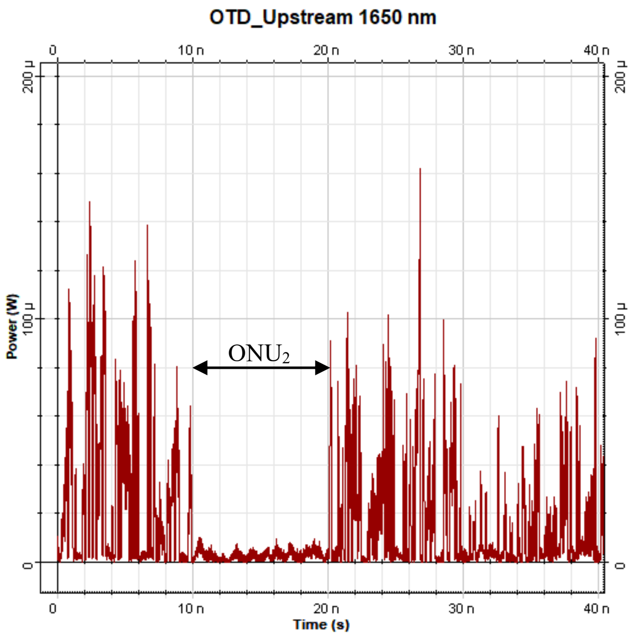

Figure 4. The monitoring signal received by TDM method in the second case with faulty condition.

In second case, the Burst mode monitoring signal does not appear in the interval from 10 nsec to 20 nsec due to ONU_2 branch is faulty, as seen in figure 4.

IV. CONCLUSIONS

In this paper, we propose a new method to monitor the physical layer faults between OLT and ONU in PON using Burst-mode FBG optical sensors. The FBG interrogation unit located in the CO provides the monitoring source for FBG optical sensor and analyzes the Burst mode FBG reflection signal returned. The ONU transmits the upstream data based on the time division multiplexing method with a time slot allocated by OLT. The simulation result showed that proposed system is cost-effective and simple solution which can monitor faults of ONU branches in PON exactly.

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REFERENCES

[1] G. Kramer, B. Mukhherjee, and G. Pesavento, “Ethernet PON (ePON): Design and Analysis of an Optical Access Network,” *Photonic Network Communication*, Vol. 3, No. 3, pp. 307-319, July 2001.

[2] Chien-Hung Yeh and Sien Chi, “ Fiber-fault monitoring technique for passive optical networks based on fiber Bragg gratings and semiconductor optical amplifier,” Optics Communications, Vol. 257, No. 2, pp. 306-310, January 2006.

[3] N. F. Naim, M. S. Ab-Rahman, A. Bakarman, and A. Bakar, “Real-time monitoring and fault locating using amplified spontaneous emission noise reflection for tree-structured Ethernet passive optical networks,” *Optical Engineering,* Vol. 52, No. 9, Septemper 2013.

[4] K. Yuksel, M. Wuilpart, V. Moeyaert, and P. Megret, “Novel Monitoring Technique for Passive Optical Networks Based on Optical Frequency Domain Reflectometry and Fiber Bragg Gratings,” *Journal of Optical Communications and Networking,* Vol. 2, pp. 463-468, 2010.

[5] National Instruments, White Papers, “Fundamentals of Fiber Bragg Grating (FBG) Optical Sensing,” October 2010.

[6] M. Werneck, B. Allil, A. Bessie and B. de Nazar, “A Guide to Fiber Bragg Grating Sensors,” May 2013.