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AN ENHANCED G-PON FAULT MONITORING TECHNIQUE USING OPTICAL SENSOR

Auwalu Usman*

Lightwave Communication Research Group, Faculty of Engineering
Universiti Teknologi Malaysia
Malaysia

Nadiatulhuda Zulkifli

Lightwave Communication Research Group, Faculty of Engineering
Universiti Teknologi Malaysia
Malaysia

Mohd Rashidi Bin Salim

Lightwave Communication Research Group, Faculty of Engineering
Universiti Teknologi Malaysia
Malaysia

Kharina Khairi

Fixed Infra Media Lab
TM Research & Development Sdn Bhd, Selangor
Malaysia

***Corrosponding author's Email:** uauwalu2@graduate.utm.my

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lat 306 Savoy Residencia, Block 3 F11/1,44000 Islamabad. Pakistan,
info@readersinsight.net

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RESEARCH HIGHLIGHTS

In this study a technique for a centralized fault monitoring and detection in Gigabit-capable Passive Optical Network (G-PON) using fiber Bragg grating (FBG) sensor is proposed. The technique detects fault once it occurs at the vulnerable locations in the fiber optic distribution link by the proposed FBG devices. Monitoring signal in the C-band is reflected by a uniform FBG with different Bragg wavelengths and reflectivities. The FBGs serve as branch identifiers in the network. The reflected signal from the FBGs is analyzed at the Optical Line Terminal (OLT) in the Central Office (CO) by an Optical Spectrum Analyzer (OSA), to identify the branch with rupture in the network. The simulated result obtained shows that the system can monitor, and detect a fault in the physical layer of the optical distribution network with negligible effects on data signal transmission.

GRAPHICAL ABSTRACT

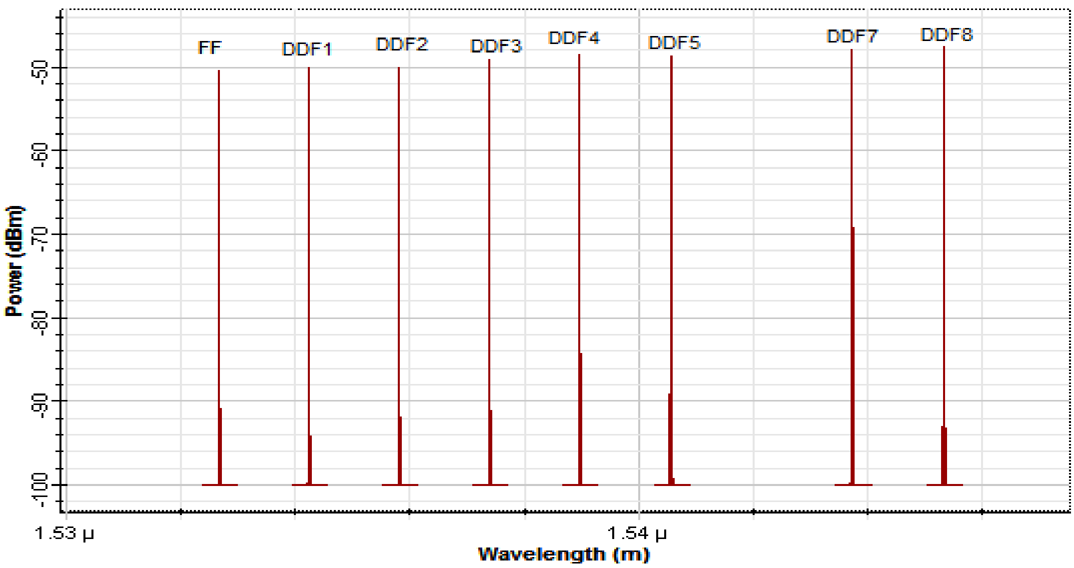

Fig. 1. Reflection spectra of the OSA indicating fiber break at the DDF6 in the DF links

RESEARCH OBJECTIVES

Failure detection in the physical layer of PON is an invaluable task for the network service providers to ensure the delivery of effective and efficient broadband services to the subscribers. It is difficult to detect a failure in the PON physical layer when the OLT/ONU management control interface cannot identify the failure branch in the fiber link (1). Hence, many telecom operators look for the centralized PON monitoring system that can easily identify and detect a fault in the fiber link. Several PON monitoring techniques have been proposed to monitor the PON physical layer (2, 3). However, most of these solutions are either too complex or expensive for actual deployment. This study intends to propose a simple and low cost method for the characterization of fault in a PON physical layer.

MATERIALS AND METHODS

In the proposed model shown in Figure 2, the modulated data signal for downstream and upstream are transmitted over 1490 nm and 1300 nm wavelength respectively. A Continuous Wave (CW) laser source is used to generate the monitoring signal at a frequency of 194 THz

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with a frequency spacing of 200 GHz, a pump laser source of 100 mw at a frequency of 980 nm is coupled with the monitoring signal through a pump coupler co-propagate (OCP) with 0 dB attenuation. Initially, the monitoring power is 0 dBm an EDFA with a pump laser is used to amplify the signal to 21 dBm. The two signals, data, and monitoring are coupled through a bi-directional optical circulator (OC), and transmitted over the feeder fiber (FF), at a distance of 20 km. The FBGs are located at the distribution and drop fiber (DDF) section, between the PSC and the ONU. A dedicated FBG is placed before the PSC to monitor the health status of the fiber link between the OLT and the remote node. These FBGs have varying center wavelengths between 1530 nm to 1540 nm determine by equation 1, with a reflectivity of > 90 % obtained as in equation 2, and a bandwidth of 125 GHz.

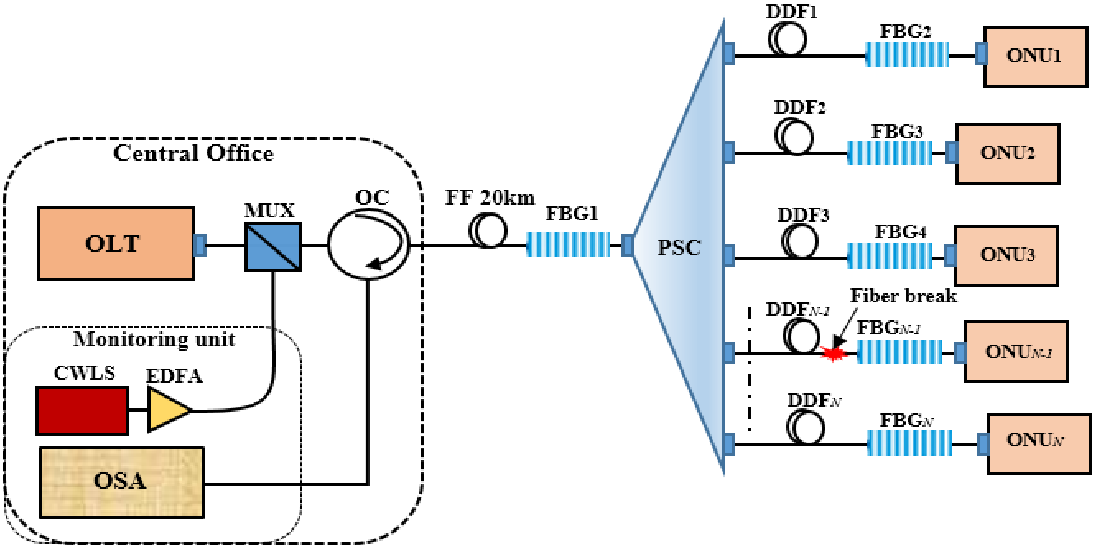

Fig. 2. FBG based centralized G-PON monitoring of fault in FTTx network

The Bragg wavelength λ_B is given as

$$\lambda_B = 2n_{eff}\Lambda \qquad (1)$$

Where n_{eff} is the effective refractive index of the fiber core and Λ is the grating period. The maximum reflectivity of the FBG can be obtain using equation 2

$$R = (1 - 10^{-\frac{d}{10}}) \times 100 \qquad (2)$$

Where R is the FBG reflectivity and d is the power dip of the spectrum (4, 5).

RESULTS

A uniform FBG sensor reflects the signal at different power levels. The FBGs operate at different Bragg wavelength that enables the signal from different sources to be reflected. The measured monitoring signal spectra are analyzed using the optical spectrum analyzer (OSA) with an optical resolution of 0.01 nm. The signals are of different power level due to a non-flattening gain of the EDFA. The maximum gain of 15.5 dB is achieved at an OSNR of 51 dB at the monitoring unit. Noise measurement of the laser source at different wavelength shows a minimum of -100 dBm and a maximum of -66 dBm.

The minimum reflected signal received is ~ -58 dBm, power degradation and missing reflection spectra in the network indicate fiber fault in the particular network branch. In normal operation of the G-PON without any fault in the optical link all, the reflections from the FBGs are present at a considerable power level of about -44 dBm to approximately -58 dBm, but under the faulty

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condition the signal power significantly drops for various DDF impairments. The reflection spectrum of Figure 7 indicates fiber break with total missing reflection at the DDF_6 link in the network. The attenuation at the 20 km FF is 0.2 dB/km bi-directional, the insertion loss for both the OC and PSC are 1 dB and 0.6 dB bi-directional respectively, and PSC insertion loss is 1.5 dB. Splice loss is 0.1 db/km and connector loss at the transmitter and receiver is 1 dB each.

FINDINGS

A simple method to monitor G-PON fault is proposed, the technique employs FBGs as a device to detect a fault in the fiber branches. The monitoring signal is generated at the OLT in the CO using an unmodulated CW laser source. The uniform FBGs located in the fiber branches reflects the monitoring signal; the reflected signal is analyzed with OSA to determine the fiber branch with fault. Significant drop of the reflected power received can recognize the status of the faulty fiber unit. Results obtained shows the capability for the scheme to monitor the network at a distance of 20 km with minimum optical reflected power received -58 dBm, at 51 dB OSNR with negligible effect on the data signal transmission.

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