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Research paper

Optical Network Monitoring System with Graphical User Interface using Various Properties of Fiber Bragg Gratings

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Abstract

This paper presents an automatic and real time domain optical network monitoring system. The system is designed using OptiSystem software to monitor a point-to-multipoint (P2MP) Time Division Multiplexing - Passive Optical Network (TDM-PON). This system is capable to monitor the health of the distribution fibers in P2MP network using Fiber Bragg Gratings (FBGs). Various FBGs with dissimilar bandwidth and reflectivity are placed in the distribution fibers. The FBGs reflection spectra are used as the branch identifiers. Any lost of reflection spectrum shows that there is a fiber failure. A system that will automatically identify the failures has also been developed. The automatic analysis with its graphic user interface (GUI) is developed using MATLAB software. It is found that this automatic monitoring system is able to monitor up to 32 users with monitoring power received of -45 dBm.

Keywords: *Fiber Bragg Grating; Passive Optical Network; Monitoring, Graphical User Interface*.

1. Introduction

Fiber-to-the-home (FTTH) Ethernet Passive Optical Network (EPON) has been acknowledged as one of the most promising communication technology which provides various communication and multimedia services [1] such as voice over IP (VoIP) and high speed internet access. Due to the increasing demand in optical network, a high quality of service (QoS) is very essential. There are several ways that have been proposed in order to monitor EPON.

[2, 3] presented passive optical access network monitoring using L-band Amplified Spontaneous Emission (ASE) source and fiber Bragg gratings (FBGs) with various bandwidth and reflectivity to monitor more customers. In [4], the residual power of Erbium Doped Fiber Amplifier (EDFA) was used as the monitoring source. In this system, FBG was inserted at each distribution fiber with distinct Bragg wavelength before the optical network unit (ONU). Each FBG will produce reflected signal which will be used to detect the health of each fiber. Thus, any lost signal indicated that there was a fiber breakdown. However, the system required expensive optical spectrum analyzer (OSA).

[5, 6] demonstrated a real time monitoring system using L-band super-luminescent diode (SLED) as monitoring source and used two types of FBGs; uniform FBG and phase-shifted FBG. Two FBGs share same Bragg wavelength to monitor more customers. Even though the system has successfully proved to monitor multiple users at limited bandwidth, it did not consider the destructive spectrum which may occur when two FBGs share the same Bragg wavelength. The used of high cost OSA is also less favored.

Based on [7, 8], it stated that the OTDR is only suitable to detect fiber breakdown for point-to point (P2P) monitoring and it is difficult to localize the failure for point-to-multipoint (P2MP) connectivity due to multiple Fresnel reflections. OTDR can only detect failure upwardly from customers' premises to central office and display a single line result at a time. This technique is less preferred due to high maintenance cost and tedious work.

According to [9-14], a P2MP fault locating technique was presented. In this technique, it used OTDR and personal computer (PC) located at central office for P2MP monitoring. An optical switch was used to monitor distribution fibers in sequence. A wavelength selective coupler was inserted at each distribution fiber to allow monitoring signal to enter for fault locating. Even though this technique is capable to monitor P2MP network using OTDR, the use of optical switch which is active device is contradicted with PON principles.

[15-17] proposed 1650 nm Brillouin OTDR for P2MP monitoring and fault locating with individually assigned frequency shifts for each distribution fiber. Although this technique is capable to locate fault in P2MP networks, the tremendous change from ordinary optical fibers to Brillouin frequency shifts (BFS) fibers make the technique less preferred.

An optical code division multiplexing (OCDM) has also been employed for P2MP monitoring [18-20]. In this technique, each distribution fiber is allocated various FBGs configurations to create unique optical codes. Each fiber is assigned different optical codes which can be created using FBGs spectra. Any missing codes indicated that there is fiber failure. However, the drawback of this technique is that it required complex signal processing at the receiver.

In this paper, a simple, centralized and automatic monitoring technique has been presented. A constructive interference has been applied to produce high amplitude of FBGs reflection spectra for the same Bragg wavelength. This is to optimize the limited bandwidth of monitoring source. This system uses L-band Amplified Spontaneous Emission (ASE) broadband source as the monitoring signal. This system is using FBGs reflection spectra as the fiber's identifiers and MATLAB graphical user interface (GUI) is also developed to detect fiber breakdown automatically. A complete optical network monitoring system is designed using OptiSystem software. The result of the monitoring system is converted into excel files and imported to MATLAB software for the automatic analysis. Thus, by using this system, more customers can be monitored automatically.

2. Research Methodology

Fig. 1. shows the principle design of optical network monitoring system. This system is simulated using OptiSystem simulation environment. An L-band (1565-1625 nm) ASE source is chosen as the monitoring signal. L-band source is chosen to avoid interference with traffic signals; downstream and upstream signals as they co-propagate along the fibers. The downstream signals are at wavelength of 1490 nm and 1550 nm and for upstream signal is 1310 nm.

An L-band source is connected using a coupler located before the 18 km feeder optical fiber. The monitoring source will be split to each distribution fiber after the optical splitter. A Fiber Bragg Grating (FBG) is inserted at each distribution fiber. The FBGs reflection spectra with various bandwidth and reflectivity are used as fibers' identifiers. FBG's spectra are detected using optical spectrum analyzer (OSA). Basically, the FBGs which share the same wavelength have different bandwidth and reflectivity. Each fiber branch will have a unique FBG spectrum. Any missing FBG spectrum indicates that there is fiber branch failure in the network.

In order to ensure high constructive FBGs spectra, the distance of the distribution/drop fiber with the same Bragg wavelength must be calculated. Thus, high constructive spectrum can be observed using OSA. The spectrum from the OSA will be further processed for automatic identification using MATLAB. MATLAB and its Graphical User Interface (GUI) are also developed for ease of use. Thus, operator can easily determine the faulty fiber using this system based on MATLAB and its GUI.

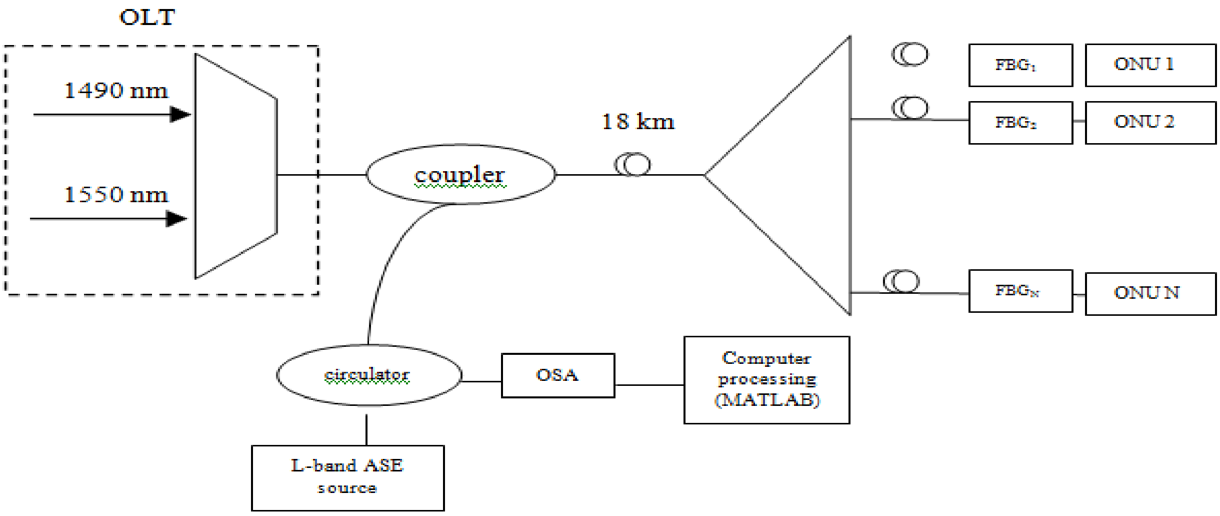

Fig. 1: PON monitoring technique based on Fiber Bragg Grating (FBG). The integrity of each drop fiber is monitored using an Optical Spectrum Analyzer (OSA). ONU is Optical Network Unit and ASE is Amplified Spontaneous Emission.

3. Result and Discussion

This optical network monitoring system can detect the failure at each ONU automatically. The system is designed to monitor the FBGs spectra up to 32 users. The losses based on real environment have been taken into account and it is simulated using OptiSystem simulation software. Based on the result shown in Fig. 2, the L-band source provides a broadband and high output power within 1565 nm to 1615 nm. Fig. 2 shows the power produced by the L-band source is approximately 1 dB that is acceptable for monitoring purposes.

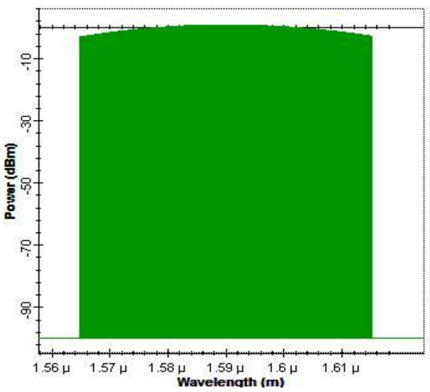

Fig. 2: L-Band ASE source

From Fig. 3, eight FBGs spectra represent for 16 customers as one Bragg wavelength is shared by two FBGs. Fig. 4 illustrates 16 users with failure at branch #3, #10 and #12. This is due to the missing spectra when comparing Fig. 3 and Fig. 4. Each spectrum consists of two customers with different bandwidth and reflectivity. The Bragg wavelength spacing is 0.5 nm to avoid any unwanted interference. In order to save the limited bandwidth of monitoring source, we placed 2 users for each Bragg wavelength. Type 1 FBG has a spectrum with bandwidth of 0.1 nm and 95% reflectivity and Type 2 FBG has bandwidth of 0.85 nm with 65% reflectivity which share the same Bragg wavelength.

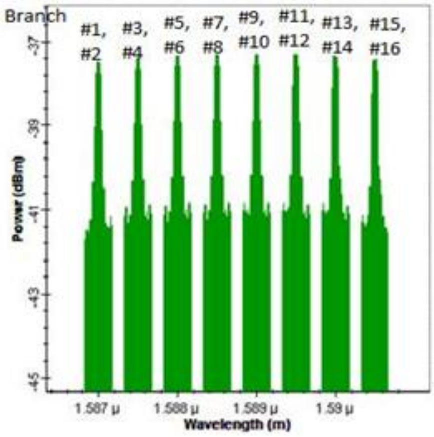

Fig. 3: Optical monitoring system for 16 users during normal condition

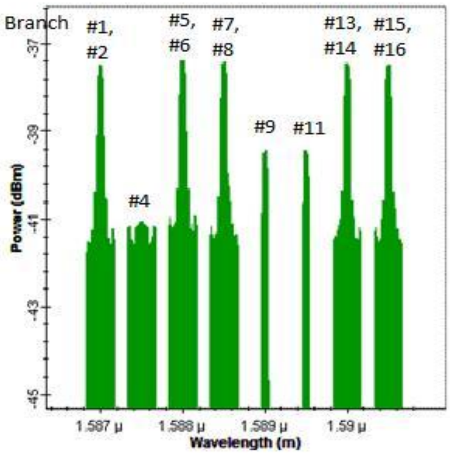

Fig. 4: Optical monitoring system for 16 users during failure condition

The length of distribution fiber must be calculated in order to produce constructive interference spectrum. Based on theory, it stated that the constructive interference signal can produces four times greater when two signals combined. Thus, FBGs spectra can easily be monitored based on the spectrum displayed by the optical spectrum analyzer (OSA). An automatic system is also developed for ease of use by suing MATLAB GUI.

Fig. 5 illustrates the interface of GUI using MATLAB software. The system will automatically inform the user once a failure is detected [7]. Thus, operator does not need to observe the FBGs spectra.

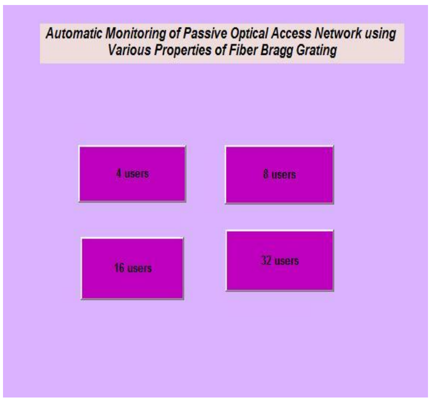

Fig. 5: MATLAB GUI of the monitoring technique

Fig. 6 demonstrates the simulation result using MATLAB software for 16 customers. The result can be seen clearly as compared to the result from OptiSystem software (Fig. 3). The blue spectrum is representing failure condition while the red spectrum is representing normal condition case. The breakdowns are located at fiber #3, #10 and #12 as displayed in Fig. 6. For each odd number of customer (#1, #3, #5 and #7), it has high reflectivity and narrow bandwidth of spectrum. Meanwhile, for even number of customer (#2, #4, #6 and #8), it has low reflectivity and wider bandwidth of FBG spectrum.

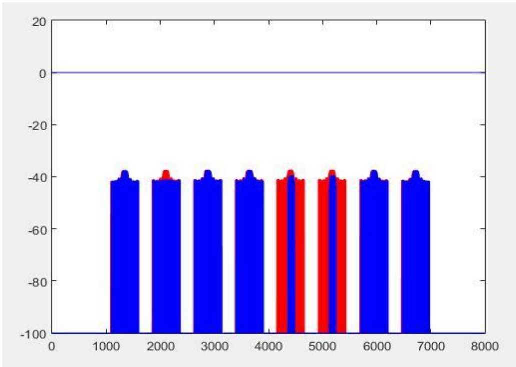

Fig. 6: Normal (red) and failure (blue) condition for 16 users in MATLAB

Based on Fig. 7, it shows the amplitude of the first FBG spectrum for 4, 8, 16 and 32 users. The simulation result is measured by using Optical spectrums analyzer (OSA). It is found that the amplitude decrease when the number of customers increase due to the high insertion loss of the optical splitter. The lowest amplitude is -34.93 dBm for 32 users.

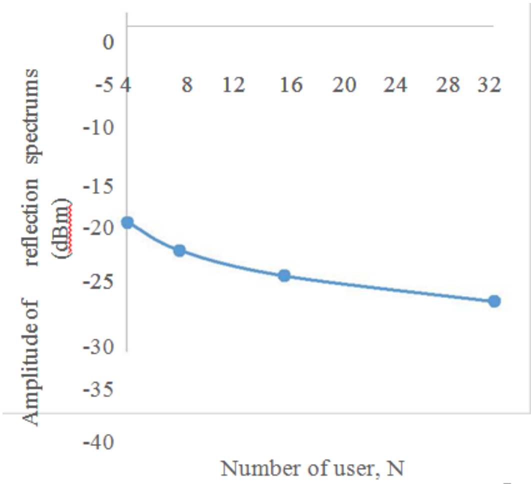

Fig. 7: Amplitude of reflection spectrums (dBm) against number of user, N

Fig. 8 illustrates the graph of monitoring power received against number of users. The result is obtained using an optical power meter and it shows that the received monitoring power is inversely proportional to the number of users. Based on the simulation result in OptiSystem software, it depicts that the minimum measurable monitoring power for 32 users is -26.172 dBm. Again, the power decrease is due to the higher insertion loss of the splitter.

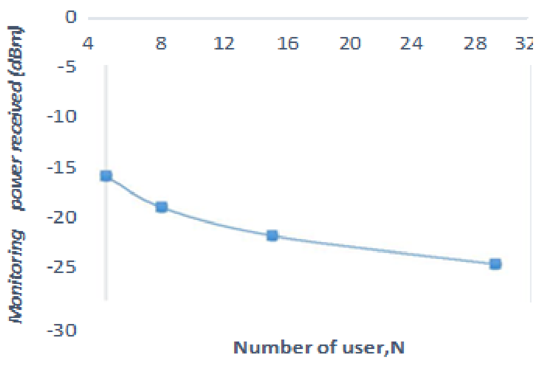

Fig. 8: Monitoring power received versus number of user

Based on Fig. 9, it demonstrates the Bit Error Rate (BER) curve against power received and it is compared between two cases, with and without monitoring system for the downstream signal. From the observation for BER performance, there is very small power penalty which is 0.2 dB for both cases. As a result, the effect of monitoring system to the network system is negligible due to very minimum effect.

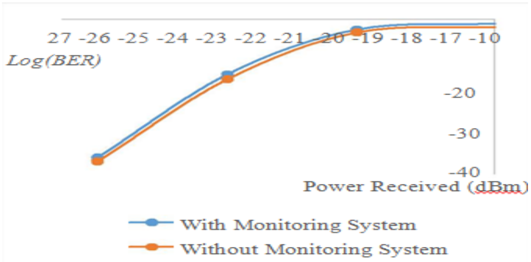

Fig. 9: BER performance against power received with and without monitoring system

4. Conclusion

An automatic optical monitoring for P2MP TDM-PON system is presented and designed in OptiSystem software. An L-band ASE source is used in the network system as the monitoring signal. A uniform FBG is placed before each ONU with different Bragg wavelength, bandwidth and reflectivity. Thus, more fibers can be monitored using limited bandwidth of monitoring source. The reflection spectra produced by FBGs are used to detect the condition of distribution fibers. Any missing reflection spectrum is considered as fiber failure. The result of the system is further processed using MATLAB software for automatic analysis. GUI method has been added for ease of use. It is found that this automatic monitoring system is able to monitor up to 32 users with monitoring power received of -45 dBm.

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