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A novel proposal of GPON-oriented fiber grating sensing data digitalization system for remote sensing network

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ABSTRACT

A novel GPON-oriented sensing data digitalization system is proposed to achieve remote monitoring of fiber grating sensing networks utilizing existing optical communication networks in some harsh environments. In which, Quick digitalization of sensing information obtained from the reflected lightwaves by fiber Bragg grating (FBG) sensor is realized, and a novel frame format of sensor signal is designed to suit for public transport so as to facilitate sensor monitoring center to receive and analyze the sensor data. The delay effect, identification method of the sensor data, and various interference factors which influence the sensor data to be correctly received are analyzed. The system simulation is carried out with OptiSystem/Matlab co-simulation approach. The theoretical analysis and simulation results verify the feasibility of the integration of the sensor network and communication network.

1. Introduction

In recent years, sensor networks have received a great deal of research interest and have been proposed in a variety of applications such as environmental monitoring, public safety and medicine etc. [1–4]. Sometimes, many projects in harsh environments are not suitable for the local detection and control. In this case, remote monitoring is a good choice. Several types of wireless sensor networks (WSNs) can be easily constructed through the use of wireless communications technology [5]. WSNs can greatly simplify the system design and have a low cost [6,7]. However, communication constraints and battery life are critical concerns due to the high demand of using electric power efficiently. In addition, data loss is also an inevitable problem because of the characteristic of the wireless medium [8]. Optical fiber sensor has no such limitations. It can be used to make distributed measurements over long distances and does not need electrical power supply [9]. The technique of optical fiber sensors has been used along 30 years ago and gets great success in the monitoring of concrete structures, offshore platform performance and ice structures [10–12]. But, relaying optical fiber sensing channel is a kind of waste and increases the cost. Implementation of a multi-functional fiber system with both communication and sensing functions is of extreme important for people to solve the practical issue and save cost. In fact, optical fiber communication network has been more and more near to us. Such as FTTC, FTTB, and FTTH have been implemented. It is possible that the optical sensing data being transmitted in public network to realize remote sensing control. So, How to realize the sensing data correct transmission, reservation and distinguish in a communication system are the key techniques for the communications and sensors working in one network.

In this paper, a novel GPON-oriented fiber grating sensing data digitalization system is proposed for remote monitoring. In which, the key factors such as sensing data digitalization, multiplexed sensing frame, and so on, are investigated carefully. Due to the original information of optical sensor exists in the form of lightwaves, it is not suitable for direct transmission in public network, and it needs first being converted to the data format so as to adapt to communication protocols. So a wavelength digitalization module is designed to complete digital conversion, and a sensing data frame module is designed to complete assembly of sensor data from every sub sensor net into frame according to the communication protocols. Thus, in the access node, a multipoint sensor frame module is designed to combine every subnet sensor data.

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The frame data is eventually sent to the remote monitoring center through public network. Therefore, the proposed scheme can not only avoid relaying sensing channel, thereby saving the cost, and support large capacity, but also increase the sensing network flexibility to some extent. The rest of this paper is organized as follows. The GPON-oriented structure of sensing system is described in Section 2 based on TDM/WDM techniques, which mainly includes the working principle of the wavelength digitalization unit, the sensing data frame encapsulation, and the GEM frame mapping. In Section 3, the system simulation and performance evaluation is carried out with OptiSystem/Matlab co-simulation approach. Finally, the conclusion is drawn in Section 4.

2. System structure and works

Fig. 1 shows the structure of the proposed multipoint sensor. The system consists of subnets, the access node, GPON as optical access network, and the remote monitoring center. Every subnet consists of light source, a coupler, sensor arrays of multiple uniform FBGs, a demodulation system, a digitalization module, and a sensor data frame module. Light source supplies the periodic broadband pulse. The sensor arrays adopt TDM/WDM technology, using WDM in each branch that same branch FBG sensors have different center wavelength, using TDM in sensor arrays and setting different time delay to distinguish each branch, so we can locate a sensor in the network accurately. The demodulation system uses arrayed waveguide grating (AWG) demultiplexer. An AWG is an integrated all-solid-state device with an array of narrow optical channels on a planar waveguide which can separate multiple wavelengths simultaneously without any mechanical movement, and it has been demonstrated superior performance [13].

As shown in Fig. 1, the reflected light from the circulator is launched into the AWG, which divides the incoming light into the multiple channels of different wavelengths of narrow band. Then the optical sensing signal is converted into a corresponding electrical digital sequence code by the wavelength digitalization system. The impulse code from every sensor in the same subnet is first assembled into subnet sensing data frame by the sensing data frame module, and then further processed at the access node into GPON-oriented GEM (Generic Encapsulation Method) frame (Detailed explanation, please refer to Section 2.2). At last frames are transmitted by GPON to remote monitoring center. GPON is an optical access technology, which has a topology structure with point to multipoint. It can provide high bit rates, such as 1.244 Gbit/s, for satisfying the demand for all kinds of new business according to G.984.3. In which, the new defined GTC layer can serve as a common transport platform to support various services [14]. Thinking that the length of sensing frame is usually fixed, the sensing system can be overlayed onto a GPON as a TDM service.

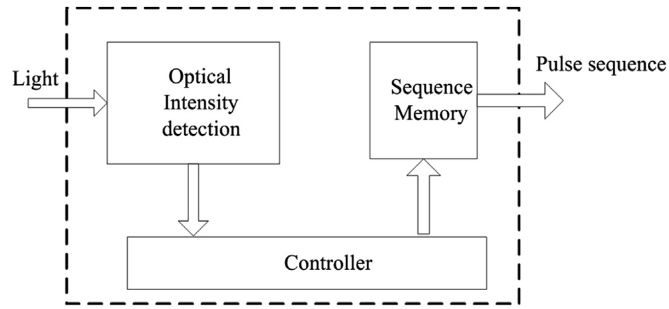

Fig. 2. Wavelength digitalization unit.

2.1. The working principle of the wavelength digitalization unit

Wavelength digitalization unit is the core component of the proposed system. As shown in Fig. 2, it's a trigger-type photoelectric device and consists of optical intensity detection section, control center and sequence memory. The unit detects the light from AWG channels and determines whether outputs the pulse sequence or not. The conversion table of FBG sensor is measured and stored in the sequence memory in advance. If the detected light intensity exceeds the threshold, the pulse sequence corresponding to the channel wavelength will be output, thus the digitalization of the sensing information is completed. The digitalized information is transported into sensing data framing module to assemble the sensing data frame. The idea of converting a pulse's wavelength to a unique time-shift (delay), for wavelength identification purposes, was proposed in the context of all-optical label switching [15]. Here, wavelength digitalization not only aims at identifying the sensing information, but also enabling the corresponding digital sequence to the GPON so as to save sensing cost. Considering that FBG sensor is sensitive to wavelength shift, so it is vital to monitor the wavelength shift of the returned Bragg signal with the changes in the measurand. Many schemes have been proposed to achieve the accurate monitoring of the wavelength shift. Among these schemes, AWG is a kind of promising solution. AWG is a passive component based on planar lightwave circuits, which has been widely used in manufacturing optical

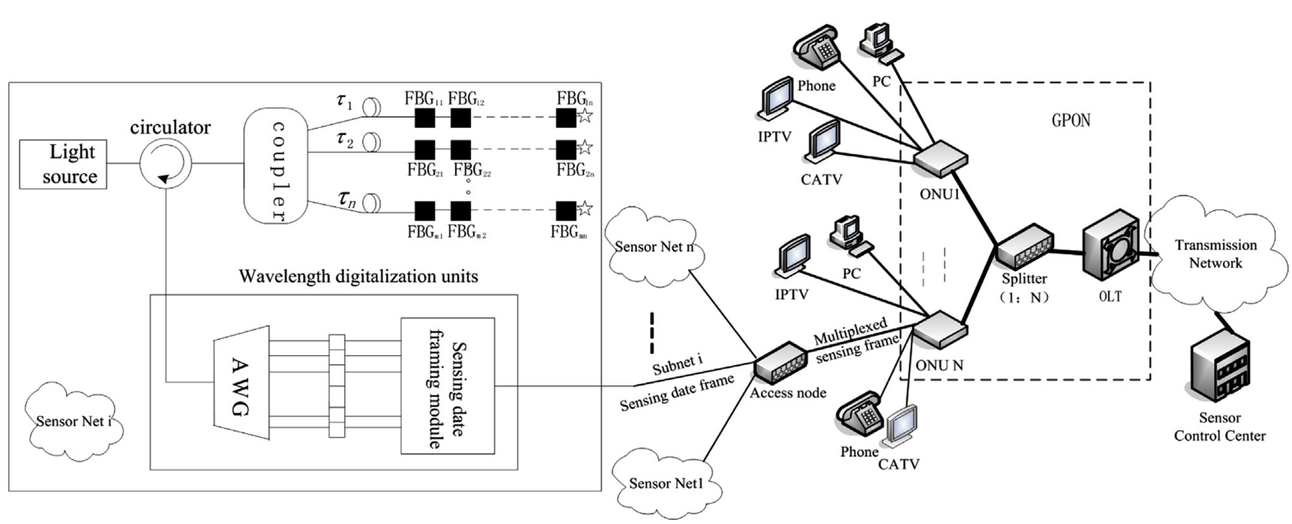

Fig. 1. Schematic of sensing data digitalization system.