A Novel Optical Sensor Platform Designed for Wireless Sensor Networks

Shuo Yang, Bochao Zhou, Tong Sun, Kenneth T.V. Grattan

School of Engineering and Mathematical Sciences and City Graduate School
City University London, London, EC1V 0HB, UK

Shuo.Yang.2@city.ac.uk, Bochao.Zhou.1@city.ac.uk, T.Sun@city.ac.uk, K.T.V.Grattan@city.ac.uk.

Abstract. This paper presents a novel design of an optical sensor platform, enabling effective integration of a number of optical fibre ('wired') sensors with wireless sensor networks (WSNs). In this work, a fibre Bragg grating-based temperature sensor with low power consumption is specially designed as a sensing module and integrated successfully into a WSN, making full use of the advantages arising from both the advanced optical sensor designs and the powerful network functionalities resident in WSNs. The platform is expected to make an important impact on many applications, where either the conventional optical sensor designs or WSNs alone cannot meet the requirements.

1. Introduction

Wireless sensor networks (WSN) have provided an effective means in acquiring information such as temperature, pressure, acceleration, vibration and specific chemicals [1]. WSNs have been reported to fulfil complex tasks, for example, for environmental monitoring, industrial sensing and diagnostics, battle tracking and security detection.

A WSN contains a large number of small scale nodes, from several to hundreds. Each node is equipped with functionalities for sensing, computing and communicating. The sensor modules in WSNs often play an important role in determining both the application areas and the performance of the WSNs. WSN nodes are small, lightweight and of low-power consumption, therefore have attracted a significant amount of interest from researchers and developers [2].

To date, most conventional WSN sensing modules, particularly those used in commercial products, are based on electrical or mechanical sensing principles [3,4]. Optical fibre sensors, however, offer advantages in applications where electrical sensors failed to perform well, for example, due to the electromagnetic interference and/or the contamination from harsh working conditions. Despite the advanced development of optical fibre sensors and extensive research into the wireless sensor network, there is limited report on the integration of optical sensors into the wireless sensor network platform. This paper thus aims to establish a novel ‘hybrid’ WSN platform to allow the seamless integration.

Temperature is one of the most important parameters to be measured in industrial process control, in scientific activities and in daily life. In this paper, an optical fibre Bragg gratting-based temperature sensor is designed specifically, with low power consumption, to serve as an optical sensor module, to replace conventional MEMS based sensor module in a WSN node.
2. Platform Design
Figure 1 shows the generic platform, designed specifically in this work and it comprises three main modules: optical sensing module, WSN module and power module.

Figure 2 shows a detailed design of the optical sensing module, which contains a SLED light source (1550nm, Dense Light), a circulator (4 ports, JDS Fitel), an InGaAs photodiode (Thorlabs) and two fibre Bragg gratings (FBGs) centred at the same wavelength (1550nm). FBG2 acts as a temperature sensor as its Bragg wavelength shifts as a function of temperature variation [5] and FBG1, located at the other port of the circulator, is used as a filter or a reference for ease of the interrogation of the sensor (FBG2) as its surrounding temperature is fixed (usually at room temperature). This specific sensor design is aimed to minimize the power consumption, by using low power light source (SLED) and a photodetector (PD), with a potential to share the same power module with the WSN. The SLED drive circuit includes a 100-mA constant current source and a high precision transimpedance amplifier (OPA380, Texas Instruments,) with an amplification gain of $10^7$ V/W. The sensor signal obtained from FBG2 with reference to the signal from FBG1 is captured by a photodiode before being converted into digital signals using an analog-to-digital converter (ADC). The overall size of the sensing module is 15cm×5.5 cm×4.5 cm, which has been carefully designed to be able to interface with the WSN module shown in Figure 1.

![Fig.1. Architecture of the platform](image1)

![Fig.2. Schematic diagram of an optical sensing module](image2)
The WSN module is integrated with computing and group communication functionalities, allowing for both data transmission via multi-hop routing and data processing. For the WSN module, CC2530F256 (Texas Instruments Inc.) is chosen as the prototype module since it is a relatively mature platform that has enough extension sockets for further functionality development. The WSN module is composed of a transceiver (CC2431, Texas Instruments Inc.), an MCU (MSP430F5438, Texas Instruments Inc.) with a built-in analog-to-digital converter (ADC) and a power source for data processing and network communication.

The power module used in the platform includes two recycled AAA sized NiMH batteries (550mAh, Ansmann) and a voltage regulator (TPS61200, Texas Instruments Inc.) which fixes the output voltage at 3.3V.

Figure 3 is a photo of a complete optical sensor platform created for a WSN. The sensing probe, which contains FBG2 at the tip, is protected by an aluminium tube and this allows the following multiple experimental tests by subjecting the probe to various temperature conditions.

3. Implementation of the new platform created
Fig.4 shows the experimental data collected from the platform when the optical fibre sensor probe is placed into a temperature chamber with temperature varies from 20°C to 80°C. The dynamic response of the sensor is obtained from the data-monitoring centre contained in the WSN module. Fig.5 shows the temperature measurement results obtained from the optical WSN node and it is noticeable that the signal intensity decreases with the increase of temperature when it varies.

The data obtained show that the remote sensor can be used effectively and conveniently in this configuration. Multiple tests have been undertaken, including long term tests. The stable output produced indicates clearly that the platform has been successfully created, which offers the seamless integration between the optical fibre sensor and the WSN.
4. Conclusion and future work

In this paper, an optical fibre platform designed with a WSN node has been created and tested successfully in this work. The platform is established through hybrid integration of an optical sensor module (temperature sensor module), TI WSN module and a power module. The positive experimental data obtained confirms the compatibility of the optical sensor with WSN nodes, taking the advantage of both the flexible optical sensor design and the network capability of the WSN.
The designed optical platform for WSNs is generic and it can be easily modified to be integrated with an array of optical fibre sensors for various industrial applications where high sensitivities and real-time monitoring are needed. The research work is still on-going and future work consists of more practical field tests using other types of optical fibre sensors to improve further the overall performance of the system and implementation of a full hybrid WSN platform.

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