# A novel wireless mobile platform integrated with optical fibre sensors

Bochao Zhou*, Shuo Yang, Tong Sun, Kenneth T.V. Grattan
School of Engineering and Mathematical Sciences and City Graduate School
City University London, London EC1V 0HB, UK

## ABSTRACT

This paper presents a novel design of wireless mobile platform which enables effective integration of a number of optical fibre sensors with an advanced mobile wireless sensor network (WSN) and allows for potential applications such as monitoring in remote and harsh environments and tracking, exploiting fully the advantages offered both by mobile WSN and by advanced optical fibre sensing technologies. The platform which was designed and implemented consists of an optical fibre sensor module and a smart mobile WSN module, which shows important advantages for mobile sensing and tracking and mesh networking. In this study, a fibre Bragg grating (FBG)-based temperature sensor was specially designed and integrated successfully into the optical fibre sensor module as an exemplar to investigate the performance of the integrated system based on the mobile WSN platform. The positive experimental results obtained have confirmed the functionality of the platform designed and demonstrated its capacity for real-time optical fibre sensor data monitoring, processing and wireless transmission. The successful creation of this type of wireless mobile platform with optical fibre sensors would be expected to make an important impact on many sectors, where either conventional optical sensor designs or WSNs alone cannot meet the systems requirements.

**Keywords:** wireless sensor network, optical fibre sensors, mobile control

## 1. INTRODUCTION

Optical fibre sensors have wide-ranging potential in sensing and measurement and have been proven to show a number of advantages over conventional sensor technology for a variety of applications [1]. However such optical fibre sensor systems are often used as 'stand-alone' devices in pre-defined positions as there is a need for extensive lengths of fibre optic cable connecting to all the sensors in an optical fibre network: in some circumstances this can be a problem. Wireless sensor networks (WSNs) have gained considerable, indeed world-wide attention in recent years and provide an effective means in acquiring information on parameters such as temperature, pressure, acceleration, vibration and chemical species, usually based on exploiting conventional Micro-Electro-Mechanical System (MEMS) sensors [2]. However, to date, there have been limited reports on the integration of optical sensors into a WSN platform. Most WSN systems do not use optical fibre sensors and thus fail to benefit from the synergy of both technologies – accessing the advantages seen in the use of a wireless sensor networks and coupling these with the benefits of the advanced design and significant capabilities of optical fibre sensors.

In addition, mobile robots have been used widely to perform a wide range of critical tasks such as exploration, search and rescue operations, and reconnaissance [3]. In recent years, extensive research has been undertaken in the field of mobile network and robot control [4][5]. All of these offers the potential to integrate mobile robots with a generic WSN platform thus to form a mobile WSN platform to overcome the limitation arising from a static WSN platform, yet coupled with advanced optical sensor system to address various sensing needs arising from different environmental context – from extremely dangerous scenarios where there are radioactive, chemical, and other industrial-based hazards to the more routine and mundane.

Based on the above requirements, in this study, a mobile WSN platform has been designed and implemented to enable the seamless integration of optical fibre sensors and mobile robots with WSNs, allowing for accessing the advantages from the advanced design of the optical fibre sensors to be coupled with the benefits of the mobility offered by the mobile robots. An optical fibre Bragg grating (FBG)-based temperature sensor has been designed specifically, with low power consumption, to evaluate the functionality of the mobile WSN platform created while supporting Graphical User

Interface (GUI) software and robot control algorithms have been developed for sensor data monitoring and mobile robot controlling.

*bochao.zhou.1@city.ac.uk; phone 0044-7403464794

## 2. PLATFORM DESIGN AND IMPLEMENTATION

### 2.1. System overview

The system designed in this programme comprises three key components: the mobile WSN platform, the base station and the data monitoring centre, which is illustrated schematically in Figure 1. Each mobile WSN platform was integrated with a WSN module, coupled to computing and group communication functionalities allowing for data transmission via multi-hop routing, an optical fibre sensor module with its in-build sensing capabilities and a mobile robot module which enables mobility of the platform and thus allowing the flexible in the sensing performance. The base station was used to collect the sensor data and then to transmit these data to a data monitoring centre for further recording, processing and display, which is based on Graphic User Interface (GUI) software and database system.

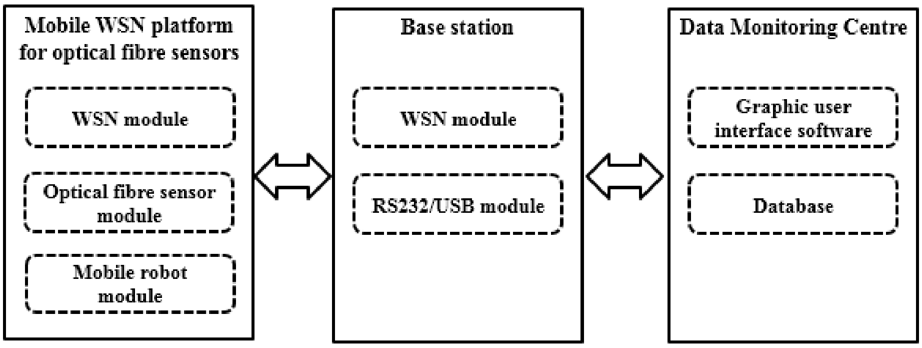
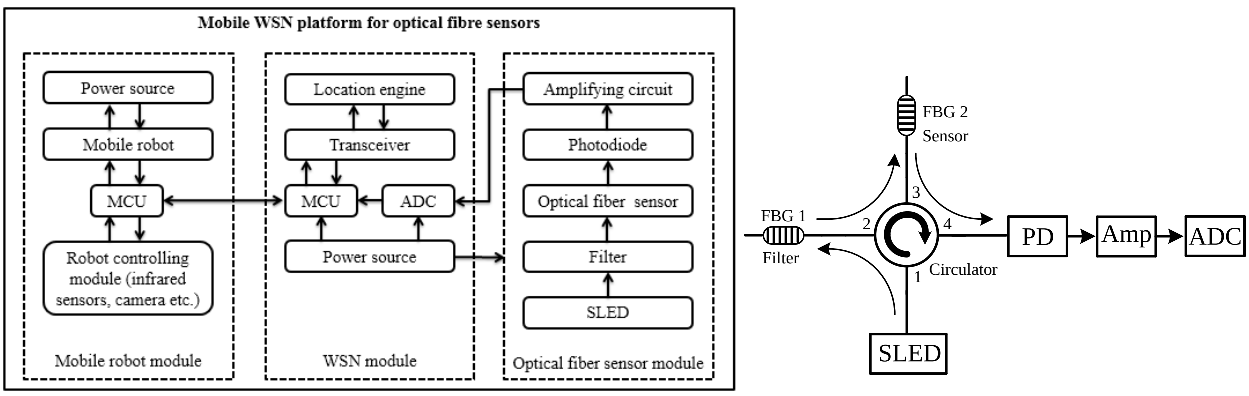



Figure 1. System architecture of the WSN platform for the optical fibre sensors.

### 2.2. Mobile WSN platform and optical fibre temperature sensor

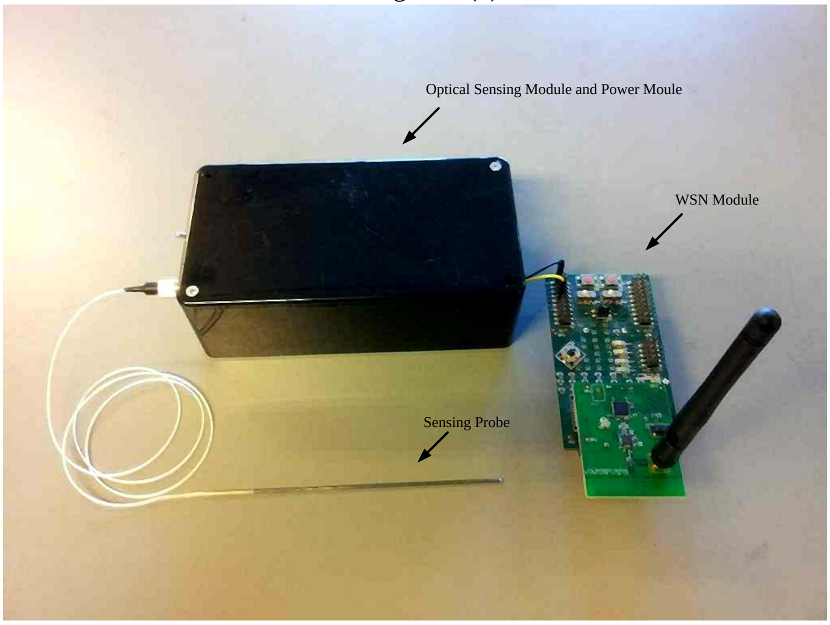
Figure 2 (a) shows the detailed design of the mobile WSN platform. The platform contained three key components: the WSN module comprising of a transceiver (CC2431, Texas Instruments Inc) with a build-in location engine, an MCU (MSP430F5437, Texas Instruments Inc), an analogue-to-digital converter (ADC) and a power source for data processing and network communication, the mobile robot module which includes an off-the-shelf robot from Active Robots Ltd integrated with a robot controlling module (video camera module etc.) and the optical fibre sensor module consisting of a SLED light source (1550nm, Dense Light), a circulator (4 ports, JDS Fitel), an InGaAs photodiode (Thorlabs) and two fibre Bragg gratings (FBGs) with the same Bragg wavelength (1550nm) – this is illustrated in Figure 2 (b). FBG2 acts as a temperature sensor as its Bragg wavelength shifts as a function of temperature and FBG1, located at the other port of the circulator, is used as a reference and located at a fixed temperature.

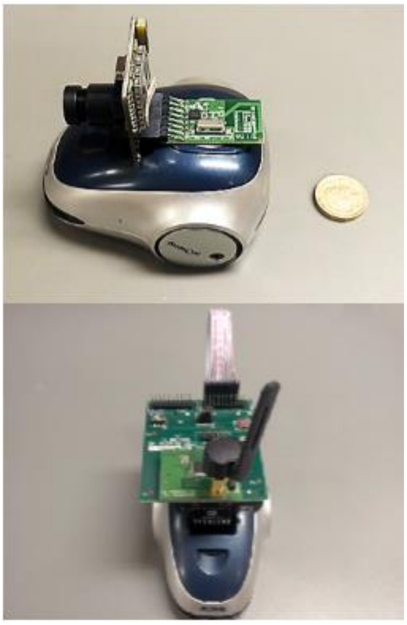



(a) (b)

Figure 2. (a) Schematic of mobile WSN platform for the optical fibre sensors; (b) Schematic diagram of the optical fibre sensor module.

Figure 3 (a) shows close-up photographs of the WSN module fully integrated with optical fibre sensor module, while the mobile robot module is illustrated in Figure 3 (b).



(a) (b)

Figure 3. Photographs of the integrated platform: (a) WSN module fully integrated with optical fibre sensor module; (b) mobile robot module integrated with a video camera and a WSN TI mote.

### 2.3. GUI software and robot control

The ZigBee standard is specifically targeted for wireless sensor network applications for reliable, low-power and remote monitoring and control and thus was chosen for this application to set-up the wireless network supporting self-healing mesh networking. At the data monitoring centre, GUI software was designed and developed using Microsoft Visual Studio 2010 for device configuration, commissioning of networks, linking devices, control of the WSNs and mobile robots, sensor data processing and display including the location and real-time camera video information.

As for the robot control, localization is of critical importance since sensing data are of more limited value if the location information is unknown, as it may be in various applications [6]. In this study, a RSSI (Received Signal Strength Indicator) localization algorithm is adopted and implemented in the robot controlling module. The physical location of the static reference nodes combined with RSSI value, which is an important parameter related to the performance of RF transmission, is used to calculate the estimated position information of the targeted blind nodes, while a real-time video camera is integrated to enhance the capability of mobile robot control.

## 3. EXPERIMENTAL STUDY AND RESULTS

To evaluate the performance of the mobile WSN platform thus developed, two separate elements of the work were considered: the communication with the optical fibre temperature sensor mounted on the robot through the WSN module as illustrated in Figure 2 (a) and a practical field test of the robot controlled using the localization algorithm and the real-time information obtained from the video camera as shown in Figure 3(b).

### 3.1. Evaluation of the WSN platform integrated with optical fibre sensors

Figure 4 shows the experimental data collected from the platform when the optical fibre sensor probe was placed into a temperature chamber with temperature varies from 20℃ to 80℃. The dynamic response of the sensor obtained from the WSN platform is displayed in the data monitoring centre. It was noticeable that the signal intensity decreased with the increase of temperature, varied from 20℃ to 80℃. The result shows clearly the successful integration of the optical fibre sensor into the WSN platform.

### 3.2. Field test of the mobile robot

The field test was designed to simulate typical practical application scenarios where the mobile robot is sent to a point of interest in order for a measurement to be made and this reported back to the investigators, giving both the location of the robot/sensor and the sensor data received at that specific position.

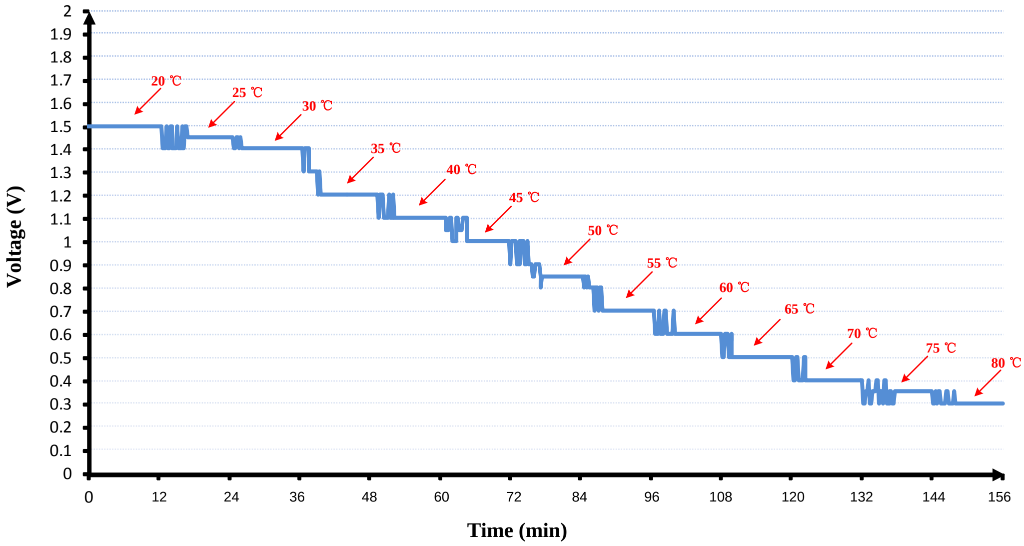



Figure 4. Dynamic response of the WSN platform integrated with the optical fibre temperature sensor (FBG2) when it is subjected to different temperature conditions.

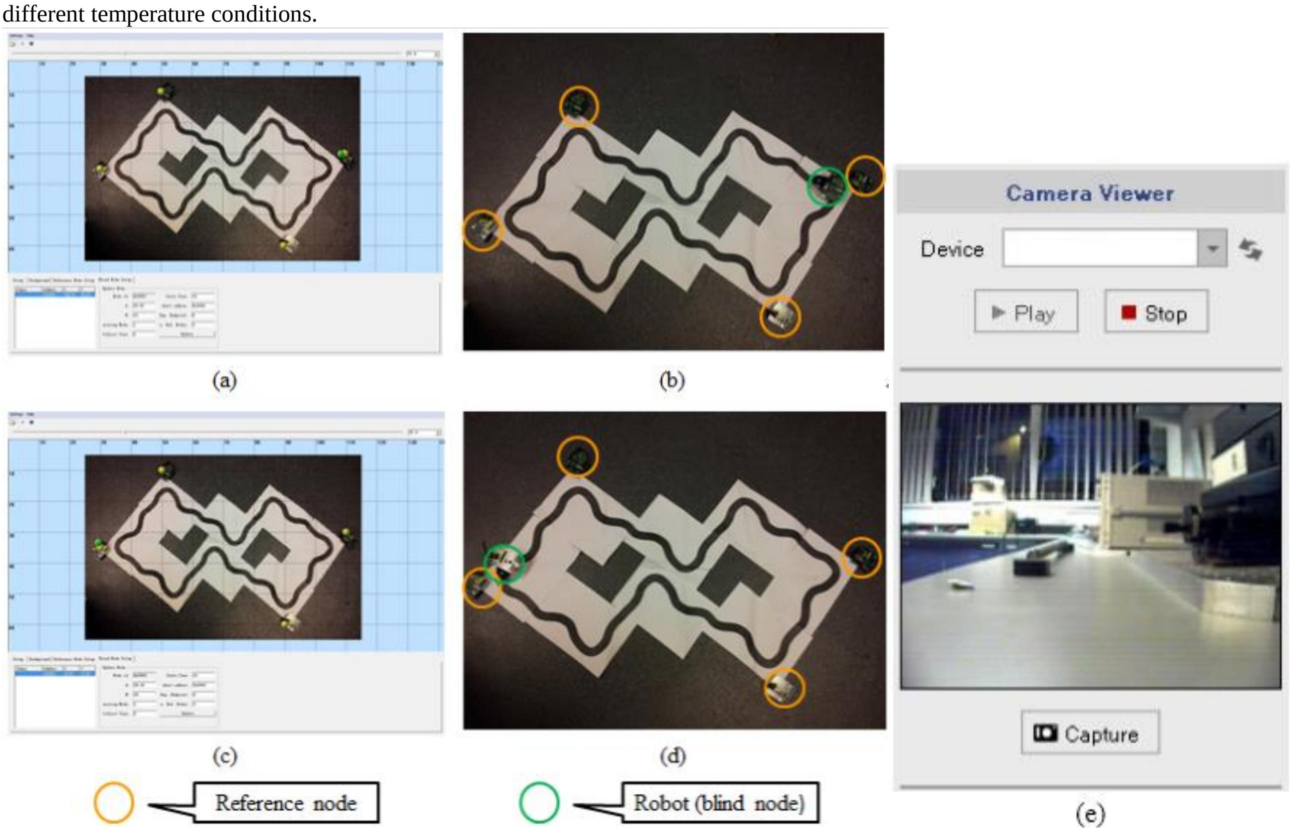


Figure 5. (a) the GUI software at data monitoring centre designed for (b) and (c) for (d); (e) GUI software for the real-time video camera.

Figure 5 shows the software interface designed for data capturing when the robot is subjected to various evaluation conditions. Four reference nodes, which have static locations labeled with different (X, Y) values, have been deployed and are indicated as the yellow points in the GUI software, shown in Figure 5 (b) and (d). The mobile WSN platform has been programmed using the line tracing exploration strategy based on the real-time video camera information (shown in Figure 5 (e)) and the estimated location is displayed at the data monitoring centre, when the targeted blind node, indicating the mobile WSN platform shown as a green point in the GUI software (in Figure 5 (a) and (c) respectively), moves from one reference node to the other, as shown in Figure 5 (b) and (d). This is communicating with the reference nodes for collecting the corresponding physical location information and RSSI values to calculate its estimated position based on the collected parameters.

## 4. CONCLUSION AND FUTURE WORK

This paper has demonstrated the design and implementation of a novel wireless mobile platform which can readily be integrated with optical fibre sensors. In this work, it was demonstrated that an optical fibre temperature sensor and an mobile robot could be successfully integrated with the WSN module to form a novel wireless mobile platform for optical fibre sensors. For demonstrating proof-of concept in this work, an evaluation of the platform using an optical fibre temperature sensor and a practical field test of the robot control based on the ZigBee localization algorithm and real-time video camera information were studied.

The integrated wireless mobile platform designed for optical fibre sensor installation is generic and it can be easily modified to be integrated with an array of different optical fibre sensors for various industrial applications where flexible mobility, high sensitivities and real-time monitoring are needed. Research is on-going to optimize data processing and robot control algorithms to allow for 'self-correction' for unexpected scenarios, taking full advantages of mesh networking involved and in the deployment of different optical fibre sensors in the platform.

## REFERENCES


[1] B. Culshaw, "Optical Fiber Sensor Technologies: Opportunities and—Perhaps—Pitfalls," *J. Light. Technol.* **22**(1), 39–50 (2004) [doi:10.1109/JLT.2003.822139].

[2] J. Yick, B. Mukherjee, and D. Ghosal, "Wireless sensor network survey," *Comput. Networks* **52**(12), 2292–2330 (2008) [doi:10.1016/j.comnet.2008.04.002].

[3] G. Tuna, V. C. Gungor, and K. Gulez, "An autonomous wireless sensor network deployment system using mobile robots for human existence detection in case of disasters," *Ad Hoc Networks*, Elsevier B.V. (2012) [doi:10.1016/j.adhoc.2012.06.006].

[4] H.-W. Tsai, C.-P. Chu, and T.-S. Chen, "Mobile object tracking in wireless sensor networks," *Comput. Commun.* **30**(8), 1811–1825 (2007) [doi:10.1016/j.comcom.2007.02.018].

[5] S. Fu, Z. Hou, and G. Yang, "An indoor navigation system for autonomous mobile robot using wireless sensor network," in *2009 Int. Conf. Networking, Sens. Control*, pp. 227–232, Ieee (2009) [doi:10.1109/ICNSC.2009.4919277].

[6] W. Chen, "A Review of Control and Localization for Mobile Sensor Networks," *2006 6th World Congr. Intell. Control Autom.*, 9164–9168, Ieee (2006) [doi:10.1109/WCICA.2006.1713773].