Demo Abstract: Smart City: a real-time environmental monitoring system on green roof

Zhihe Zhao, Jiaheng Wang, Chenxu Fu
Xi'an Jiaotong-Liverpool University, SuZhou, China
{Zhihe.zhao14, Jiaheng.Wang15, Chenxu.Fu15}
@student.xjtlu.edu.cn

Dawei Liu, Bailiang Li
Xi'an Jiaotong-Liverpool University, SuZhou, China
{Dawei.Liu,Bailiang.Li}@xjtlu.edu.cn

***Abstract* — The research on the green roof is of great importance in the field of urban beautification and improving ecological effect. According to the previous research, plants have shown a significant impact on the absorption of PM2.5. Therefore, it is justified that the appropriate planting design or some particular combinations of plants can be considered as a solution, dealing with the urban fine particulate matter (PM2.5). This paper presented a work in progress on developing wireless sensor networks (WSN) system based on a prototype wind tunnel, which is used for the simulation of the green roof. Several data collection processes are handled by this system, where the concentration of PM2.5, wind speed, temperature & relative humidity are obtained and stored in the database simultaneously. Additionally, users are able to real-timely define their commands in details, controlling the sensor's height through a GUI on the website. Experimental and simulation results and measurements have verified the validity of the wind tunnel module as well as the reliability of the sensor network. The system can be operated on thousands of devices when the packet delay maintained in a low level.**

Index terms* — *wireless sensor networks, green roof, wind tunnel, stable and flexible architectures, PM2.5 concentration monitoring.

INTRODUCTION

In 2014, 92% of the world population was living in places where the WHO air quality guidelines levels were not met [1]. Especially for the particulate matter with diameter equal or smaller than 2.5 micrometers, which acts as a major environmental risk to health, Therefore, it is urgent to look for ways to mitigate the PM2.5 pollution [1]. Green roofs becomes very popular in urbanized area to fight air pollution. Green roofs are referred as roofs with planted vegetation on top of buildings, which have been proved to be an effective way to mitigate air pollution [2]. One of the main purposes of this work is to design a portable wind tunnel system which can be used outdoors to monitor the roof vegetation performance on air cleaning under different meteorological conditions. By virtue of the success of Internet of Things(IOT) technology, Wireless Sensor Networks (WSN) is selected as the solution dealing with works that include integrating sensing, data processing, packet formation and wireless transmission, which is attributed to the combination of a cluster of low costs but easily-deployed nodes [3]. The monitoring system is designed in parts, where each of unit can be freely joined or separated from the network and adjusted independently, meeting different demands. In this project, we built a real-time environment measurements monitoring and duplex communication and control system, attached on a prototype outdoor wind tunnel so as to simulate complex environmental changes occurred in the urban outdoor space. The system itself can be applied to for urban environmental monitoring.

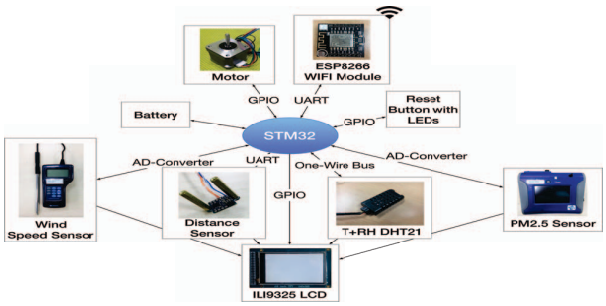

Fig. 1. Wireless sensor hardware architecture

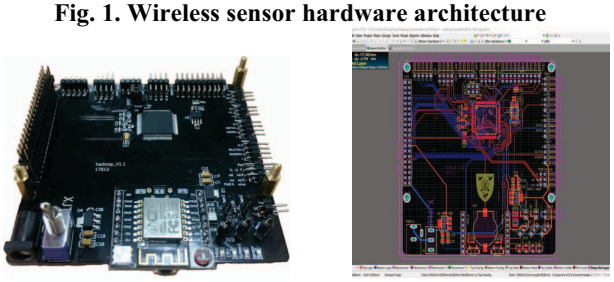

Fig. 2. PCB of the wireless

SYSTEM ARCHITECTURE

A. General Overview

As is shown in Figure 1, all sensors together with other peripheral devices are attached to a core micro-controller where the data are concentrated and are communicated.

B. Hardware Infrastructure

Considering that outdoors environment may exacerbate aging of the device, the STM32F103VET6 was selected. The program occupies 72% of flash memory and 4.2% of SRAM. All related sensors are attached to the MCU, operating simultaneously. All sensors are chosen to respect a reasonable range and requirement of accuracy. In the light of that the distribution of particulate matter has a different pattern at a different height, sensors

0-7695-6387-2/18/$31.00 ©2018 IEEE
DOI 10.1109/IoTDI.2018.00049

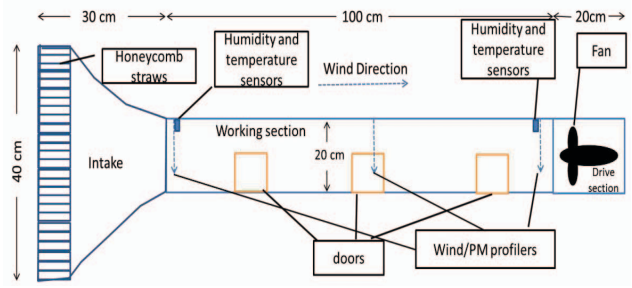

Fig. 3. Architecture of the wind tunnel

Fig. 4. Front panel of the WEB application

are transported to a different height, usually fixed at the average height of the plants, to measure data. The Printed Circuit Board (PCB) shown in Figure 2 was designed as double sides and all components including the MCU, WI-FI module, power circuits are on the top layer. The bottom layer is used for traces.

The wind tunnel design as well as the established mechanical structure are demonstrated in Figure.3.

C. Software Design

As one of the most common IOT applications employing a large number of wireless sensors, WSN model is the archetype of this system. All environmental sensors work as input via different protocols such as SPI, 1-wire bus, UART. The MCU send the monitoring packet, messages consist of header, order, data contents, direction, CRC (Cyclic Redundancy Check) and the end of frame observing the designed data transmission protocol, via USART at PA9 (TX) to ESP8266, the WI-FI module, according to an established period (1 second by default) which can be set on the website.

Considering the accessibility of this monitoring system for the green roof, a website was particularly designed and established to visualize the data acquired from the multiple sensors on which real-time data is displayed and an up-to-date dynamic line chart is rendered accordingly. The front end system is shown in Figure 4. The data collected also stored in the database for further retrieval and analysis.

RESULTS

Data were recorded in a three-month experiment time span when the weather condition of the high T&RH difference has been experienced. Abnormal measurements were eliminated by the moving average algorithm on the software level, and on the level of hardware. In the light of the application of WSN, it is essential for the system to satisfy the real-time requirement. Therefore, corresponding packet delay tests were conducted in situations where the level of QoS in Message Queuing Telemetry Transport (MQTT) data transmission are different. The subject in the test is the MQTT publisher whose packet delay performance can be simulated via JMeter-MQTT, a third-party open source [4].

Aimed at studying on the problem of urban air pollution which highly correlated with the excessive particular matter in the air. The work develops a real-time wireless sensor system simulating the scenario of a green roof that monitors the PM2.5 and other related sensor parameters such as relative humidity, temperature, wind speed based on the IEEE 802.11b/g/n standards. The main goal of the approach is to justify the stability and data accuracy of the prototype which was designed and tested. Considering the fact that real applications of green roofs in the city requires multiple concurrent devices online, the performance of throughout in the monitoring system was elaborately evaluated and optimized for concurrent connections. And we carried out multiple experiments to examine and evaluate the system in terms of key points overall performance, latency and accuracy of data.

ACKNOWLEDGMENT

This project is financially supported by a Summer Undergraduate Research Fellowship (SURF 201762) from Xi'an Jiaotong-Liverpool University. We also thank Dr Bingjian Liu, Mingyang Wang, Chunyu Chen and many other fellow students for their support on experimental design and wind tunnel construction.

REFERENCES

[1] (2016, Sep). *Ambient (outdoor) air quality and health* [Online]. Available: http://www.who.int/mediacentre/factsheets/fs313/en/

[2] K. Vijayaraghavan, "Green roofs : A critical review on the role of components, benefits, limitations and trends," *Renewable and Sustainable Energy Reviews*., vol. 57, pp. 740–752, May 2016.

[3] M. Magno, V. Jelicic, S. Member, M. Magno, and D. Brunelli, "Context-Adaptive Multimodal Wireless Sensor Network for Energy-Efficient Gas Monitoring Context-Adaptive Multimodal Wireless Sensor Network for Energy-Efficient Gas Monitoring," *IEEE Sensors Journal*., vol. 13, no. 1, pp. 328–338, Jan, 2013.

[4] (2017, Dec). *JMeter Performance and Load Testing* [Online]. Available: https://keyholesoftware.com/2017/12/11/jmeter-performance-and-load-testing/