Air Quality Monitoring System

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INTRODUCTION

Climate change has been causing significant impacts on people's living conditions, stability, and socio-economic development status in the Lower Mekong River Basin day by day. Besides, due to population growth, the rapid increase of industrialization, as well as indiscriminate use of chemical fertilizers and pesticides in agriculture, are causing serious impacts on the environment, climate, and public health. Air quality is getting worse noticeably, especially in urban areas where high population density and many industrial parks. World Health Organization (WHO) announced that there are approximately 4.2 million premature deaths globally are linked to ambient air pollution [1]. Air Quality Index is a metric to assess how polluted the air is. Recently, air pollution levels in Hanoi and Ho Chi Minh City have reached alarming levels [2]. According to Vietnam's AQI ranking (see Table I), the index reaches a threshold of over 150 Manuscript received June 17, 2020; revised February 5, 2021.

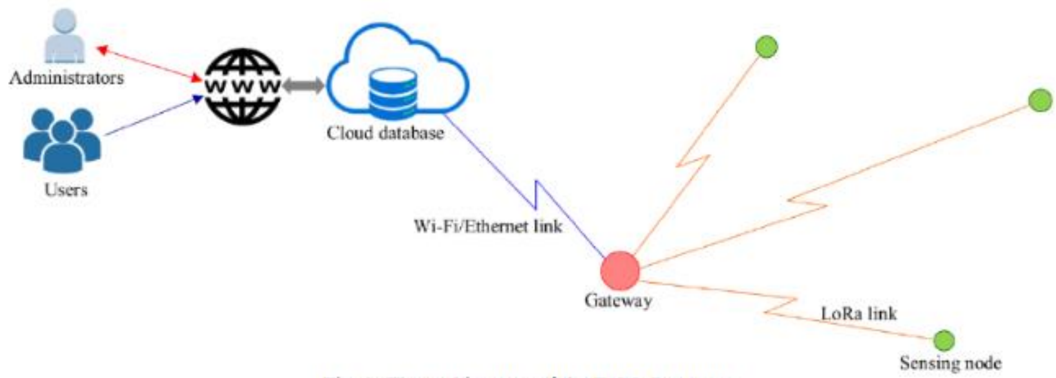

Fig. 1. The architecture of the EnMoS system.

Hardware System Overview

The objective of the LoRa wireless sensor network is to establish radio links between the gateway and the sensing nodes for gathering air quality factors. For the sake of simplicity and costs, we use either Raspberry Pi Zero W with Wi-Fi or Raspberry Pi Zero for control boards at a gateway and sensing nodes respectively. We designed and implemented a printed circuit board stacked on both control boards. It helps to wire a radio transceiver and sensors up to the control board for reducing attenuation and interference. For radio communication, Modtronix inAir4 module, a compact LoRa transceiver, offers low power consumption and long-distance radio link for sensing applications

➢ Sensor Used

Utilizing the advances of Micro Electro Mechanical Systems (MEMS), light scattering, non-dispersive infrared (NDIR), and proven sensing principles, we use various state-of-the-art sensors for better measurement of major air pollutants [20]–[23]. They must be appropriate for the application requirements, taking into account quality, responsiveness, reliability, and long service life

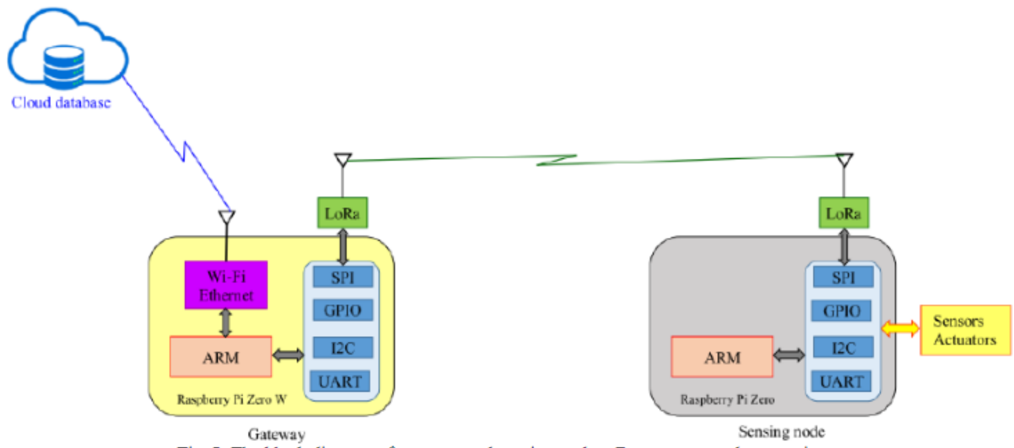

Fig. 2. The block diagram of gateway and sensing nodes: Components and connections.

➢ LoRa Transceiver

Semtech's long-range (LoRa) has been one of the well-known long-range technologies used in large-scale remote sensing systems. It provides accommodation between low data rates and long-distance radio links with different configurations of major parameters: Carrier Frequency (CF), Bandwidth (Bw), Spreading Factor (SF), and Coding Rate (CR). Using the LoRa chip, communication links can reach up to several kilometers in urban areas and tens of kilometers in rural areas

Fig. 3. A LoRa inAir4 module with a 7-dBi antenna.

➢ Hardware Design and Implementation

An adaptor Printed Circuit Board (PCB) is designed to connect electrical or electronic devices using conductive tracks in order to improve the stability of the system as well as reduce interference. LoRa inAir4 module and sensors are soldered onto the PCB to wire them together. The adaptor interfaces with Raspberry Pi via GPIOs header conveniently. A PCB computer-aided-design (CAD) tool is employed to ensure the proper layout of components and validate operations of circuitry. After that, a computer numerical control (CNC) machine prototyping can produce the PCB quickly, as shown in Fig. 4.

(a) (b)

Fig. 4. (a) 3D PCB Design Presentation (b) PCB of adaptor board.

SOFTWARE DEVELOPMENT

➢ Data Collection

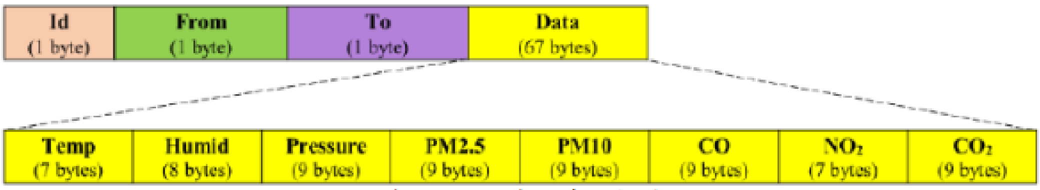

Fig. 7. Formation of payload.

A LoRa star network is deployed to collect environmenta data to a gateway from many sensing nodes distributed in a wide area (see Fig. 1). Sensing data at sensor nodes, with data formation as illustrated in Fig. 7, needs to be sent to the gateway reliably so that a trick scheduling communication must be programmed. The LoRa chip operation has to be controlled by a Python program running on an ARM processor equipped on Raspberry Pi. It is critical to executing interrupt routines to control data exchange within the network effectively. At the gateway, air quality factor values collected from sensing nodes are uploaded to a cloud server either through Wi-Fi or the Internet. The obtained data are inserted into a Firebase real-time database and the calculation are executed for AQI values.

$$AQI = \frac{AQI_{High} - AQI_{Low}}{C_{High} - C_{Low}} \times \left(C_{Input} - C_{Low}\right) + AQI_{Low} \quad (1)$$

➢ Web Application

The web page at address https://enmos-ctu.web.app/ is built in order to provide an interactive map along with the corresponding graphs for air quality parameters. It is convenient for people to access the information from any web browser running on a variety of hardware platforms and operating systems. The level of pollutants in the air, such as PM2.5, PM10, and CO_2 are presented on separate graphs to observe easily

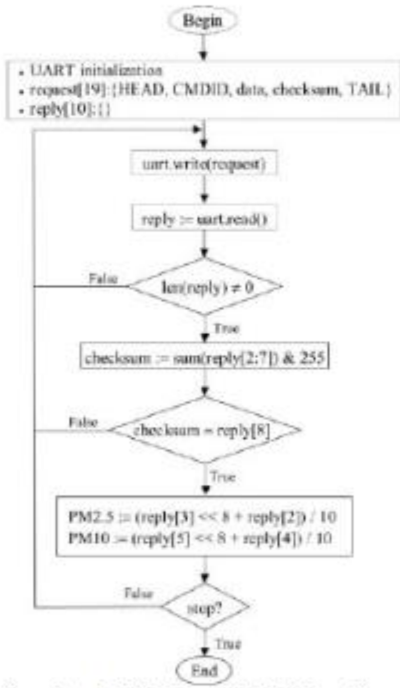

Fig. 8. Flowchart of reading PM2.5 and PM10 data from the SDS011 sensor.

CONCLUSION AND FUTURE WORK

In this paper, we presented the implementation of an IoT-based air quality monitoring system, namely the Environmental Monitoring System (EnMoS) system. The system allows AQI monitoring for a wide area in real time with a visual web map application in light of long-distance wireless technology and cloud database service. We deployed a LoRa star network consisting of a gateway for data collection, then uploading to cloud server and three wireless sensing nodes at three typical laboratories on campus. Each sensing node equips sensors for measuring environmental factors for AQI calculation such as particulate matter (PM2.5 and PM10), CO_2, air pressure, temperature, and humidity. Experimental results show that node deployment strategies and methods have a significant impact on the efficiency of air quality sensing. For future work, it is critical to carry the calibration phase with a reference or standard of known and high accuracy for evaluation and validation of the values of all sensors in the proposed system. We also plan to extend the system for air quality monitoring in an area of few tens of square kilometers, for example, all labs on Campus II of Can Tho University. Moreover, based on the positive results of this research, the EnMoS may be applicable for various surveillance applications, for example, saltwater intrusion monitoring, structural health monitoring, and so on