UAV Mounted IoT-based Air Pollutant Measurement System

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Abstract— Air quality information close to pollution sources is tough to obtain, notably when sites are advanced, have physical barriers, or are themselves moving. Tiny Unmanned Aerial Vehicles (UAVs) provide new approaches to pollution and atmospheric studies. The purpose of the study is to develop drones or unmanned aerial vehicles that are able to effectively and efficiently detect, quantify and monitor pollutants in the air in the environment, and the other purpose of the study is to develop air pollution monitoring systems that are compact in dimensions. These studies were implemented and an air pollution monitoring system was designed which is able to measure parameters of air pollution such as PM10, PM 2.5. During the design process, critical decisions were taken to select the type of UAV, type of air pollution sensor and the position of the sensors on the UAV. We aim to provide a medium to understand the changes in air pollution parameters as the UAV can be freely maneuvered in the premise. The data collected from these sensors is stored in IoT based cloud platform directly. By doing so we were able to obtain the data in real-time and stored it for further analysis. The UAV hovered at various points of interest in the city and the level of air pollution was known in real-time.

Keywords— Air quality, Unmanned Aerial Vehicles, PM10, PM 2.5, sensors, IoT, cloud.

I. INTRODUCTION

Industrial growth has brought unforeseen technological advances to our societies. Unfortunately, the price to pay for these advances has been an increase in air pollution worldwide, affecting both our health and our lifestyle. The use of unmanned aerial vehicles has become more common in the present time and the technology is developing at a very fast rate. Due to the rapid technological advancement, the UAVs come in different types and capacities. Unmanned Aerial vehicles are often referred to as drones [1]. These drones have opened up new possibilities in the field of atmospheric research. This papers main focus is regarding environmental monitoring activities. People are becoming more aware of the impact of air pollution-related issues on their day to day life [2]. The present monitoring system that is stationed at different locations in the city is not able to meet the dynamic nature of pollution pattern in the cities. UAV can help understand the nature of pollution the populated cities. Air pollutants known as particulate matter are a complex mixture of microscopic solids and liquid droplets with some particles such as dust, dirt, soot or smoke large enough or dark enough to be seen with the naked eye. Sensors which have the capability to detect the particles are deployed to study even the smallest particulates using unmanned aerial vehicles to carry such instruments into the sky and analyze what is in the air we breathe [2]. The internet of things, or IoT, is a system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers (UIDs) and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction. The rest of the paper is organized as follows. The hardware component description to implement the project is explained in Section II. The software description to implement the project is presented in Section III. Project description and results are presented in Section IV and paper is concluded in Section V.

II. HARDWARE COMPONENT DESCRIPTION

The main components used in the setup are: Quadcopter, Particulate matter sensor, Microcontroller NodeMCU which is an open-source IoT platform. It includes firmware which runs on the ESP8266 Wi-Fi SoC from Espressif Systems, and hardware which is based on the ESP-12 module. The term "NodeMCU" by default refers to the firmware rather than the development kits. The firmware uses the Lua scripting language. It is based on the eLua project and built on the Espressif Non-OS SDK for ESP8266. It uses many open source projects, such as lua-cjson and SPIFFS. The block diagram of the project is shown in Figure 1.

A. APM 2.8 Flight Controller
B. NodeMCU
C. Quadcopter Setup
D. PM 10 and PM 2.5 Sensor

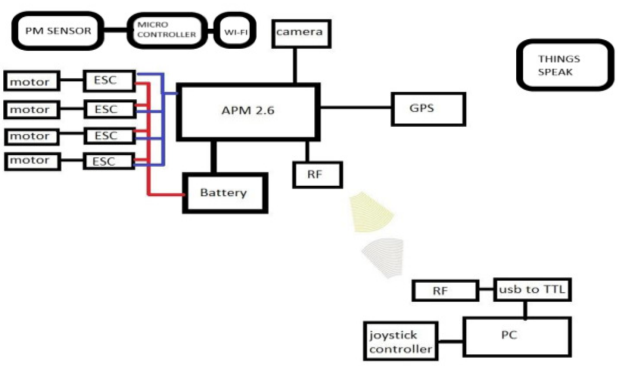

Figure 1. Block Diagram

A. APM 2.8 Flight Controller

APM 2.8 Multicopter Flight Controller is upgraded version of 2.5 2.6 with Built-in Compass for FPV RC Drone Aircraft is the new APM 2.8 flight controller. The sensors are exactly the same as the APM 2.6 flight controller, however, this has the option to use the built-in compass, or an external compass via a jumper. The APM 2.8 Multicopter Flight Controller is a complete open source autopilot system and the bestselling technology that won the prestigious Outback Challenge UAV competition. It allows the user to turn any fixed, rotary wing or multirotor vehicle (even cars and boats) into a fully autonomous vehicle; capable of performing programmed GPS missions with waypoints [7]. This revision of the board has an optional onboard compass, which is designed for vehicles (especially multi-copters and rovers) where the compass should be placed as far from power and motor sources as possible to avoid magnetic interference. (On fixed wing aircraft it's often easier to mount APM far enough away from the motors and ESCs to avoid magnetic interference, so this is not as critical, but APM 2.8 gives more flexibility in that positioning and is a good choice for them, too) [8]. This is designed to be used with the 3DR uBlox GPS with Compass so that the GPS/Compass unit can be mounted further from noise sources than APM itself.APM 2.8 Multicopter Flight Controller requires a GPS unit for full autonomy. This controller is shown in Figure 2.

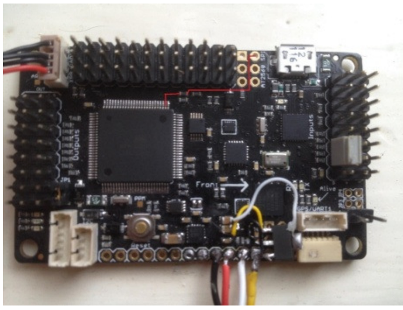

Figure 2. APM 2.8

B. NodeMCU

NodeMCU is an open-source firmware and development kit that helps you to prototype or build IoT product. It includes firmware which runs on the ESP8266 Wi-Fi SoC from Espressif Systems, and hardware which is based on the ESP-12 module. The firmware uses the Lua scripting language. It is based on the eLua project and built on the Espressif Non-OS SDK for ESP8266 [4].MCU stands for MicroController Unit - which really means it is a computer on a single chip. A microcontroller contains one or more CPUs (processor cores) along with memory and programmable input/output peripherals. They are used to automate automobile engine control, implantable medical devices, remote controls, office machines, appliances, power tools, toys, etc.NodeMCU Development kit provides access to these GPIOs of ESP8266. The only thing to take care is that NodeMCU Devkit pins are numbered differently than internal GPIO notations of ESP8266 as shown in below figure and table. For example, the D0 pin on the NodeMCU Devkit is mapped to the internal GPIO pin 16 of ESP8266 [6]. As Arduino.cc began developing new MCU boards based on non-AVR processors like the ARM/SAM MCU and used in the Arduino Due, they needed to modify the Arduino IDE so that it would be relatively easy to change the IDE to support alternate toolchains to allow Arduino C/C++ to be compiled for these new processors. They did this with the introduction of the Board Manager and the SAM Core. A "core" is the collection of software components required by the Board Manager and the Arduino IDE to compile an Arduino C/C++ source file for the target MCU's machine language. Some ESP8266 enthusiasts developed an Arduino core for the ESP8266 WiFi SoC, popularly called the "ESP8266 Core for the Arduino IDE". This has become a leading software development platform for the various ESP8266-based modules and development boards, including NodeMCUs [5]. Figure 3 shows the pin diagram of the NodeMCU.

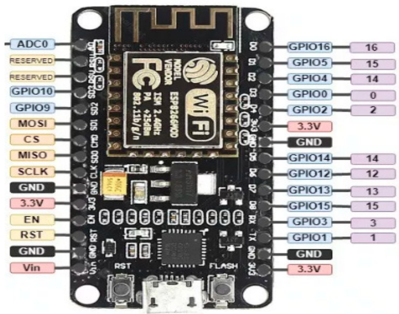

Figure 3. Pin diagram of Node MCU [4]

C. Quadcopter Setup

The quadcopter is a harmonious working of different components such as Frame, Brushless motors, Power distribution board, Ant vibration mounts, landing gear, transmitter, receiver, Telemetry kit, camera, video transmitter, video receiver, Electronic speed controllers. Due to technological advancements, these components are easily available at a fraction of the price that they were a few years ago. A setup of the quadcopter with the APM flight controller is shown in Figure 4.

Figure 4. Quadcopter Setup

D. PM 10 and PM 2.5 Sensor

The Nova PM Sensor uses the principle of laser scattering, it can detect a particle ranging between 0.3 to 10μm in the air. It with digital output and built-in fan it provides a stable and reliable output. Light scattering can be induced when particles go through the detecting area. The scattered light is transformed into electrical signals and these signals will be amplified and processed. The number and diameter of particles can be obtained by analysis because the signal waveform has certain relations with the diameter of the particles [9]. This sensor is used to measure PM 10 and PM 2.5 air pollutants and shown in Figure 5.

Figure 5. Nova PM sensor SDS011 [9]

III. SOFTWARE DESCRIPTION

A. Mission Planner

Mission Planner is a ground control station for Plane, Copter and Rover. It is compatible with Windows only. Mission Planner can be used as a configuration utility or as a dynamic control supplement for your autonomous vehicle. Here are just a few things you can do with Mission Planner: Load the firmware (the software) into the autopilot board (i.e. Pixhawk series) that controls your vehicle. Setup, configure and tune your vehicle for optimum performance. Plan, save and load autonomous missions into youautopilot with a simple point-and-click way-point entry on Google or other maps. Download and analyze mission logs created by your autopilot. Interface with a PC flight simulator to create a full hardware-in-the-loop UAV simulator. With appropriate telemetry hardware you can: Monitor your vehicle's status while in operation [10]. Record telemetry logs which contain much more information the onboard autopilot logs. View and analyze the telemetry logs. Operate vehicle in FPV (first-person view) as depicted in Figure 6.

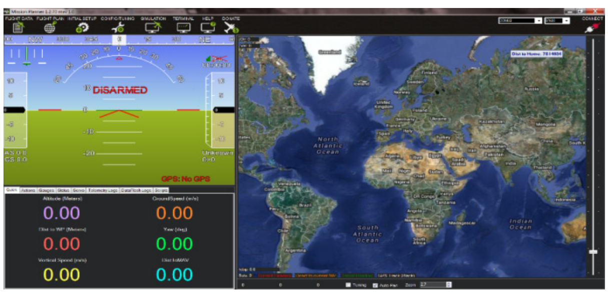

Figure 6. The user interface of Mission Planner

B. ThingSpeak IOT Cloud Analytical Platform

ThingSpeak is an open-source Internet of Things (IoT) application and API to store and retrieve data from things using the HTTP protocol over the Internet or via a Local Area Network. ThingSpeak enables the creation of sensor logging applications, location tracking applications, and a social network of things with status updates.ThingSpeak has integrated support from the numerical computing software MATLAB from MathWorks, allowing ThingSpeak users to analyze and visualize uploaded data using Matlab without requiring the purchase of a Matlab license from Mathworks [11].ThingSpeak has a close relationship with Mathworks, Inc. In fact, all of the ThingSpeak documentation is incorporated into the Mathworks' Matlab documentation site and even enabling registered Mathworks user accounts as valid login credentials on the ThingSpeak website.

IV. EXPERIMENTAL SETUP

The quadcopter was assembled and the firmware was flashed on the APM 2.8 Flight controller using the Mission Planner software. While flashing the firmware Quadcopter was selected as the UAV of choice. After flashing the software, the sensors built on the APM 2.8 Flight controller board were calibrated. Few flight tests were conducted and the stability of the quadcopter was ensured by tuning the PID controller. The Node MCU and sensor were mounted in such a way that the sensor receives less wash from the propellers of the quadcopter. The program was uploaded on the NodeMCU to send the readings from the sensor to the cloud storage and analytical platform ThingSpeak. The data is communicated through the inbuilt Wi-Fi capabilities of the NodeMCU. Therefore, a stable and high range Wi-Fi signal is required for the operation. The location of the quadcopter when airborne is displayed on mission planner software when the radio telemetry is used. The experimental setup is shown in Figure 7.

Figure 7. Experimental Setup

The test was carried out at Banjara Hills, Hyderabad, India adjacent to the main road when there was low traffic density and the following results of PM 2.5 and PM 10 are observed. Theses sensor values were sent to the ThingSpeak server every 3secs. Figure 8 and 9 depicts the values of PM 2.5 and PM 10 air pollutants obtained from the ThingSpeak server in real-time.

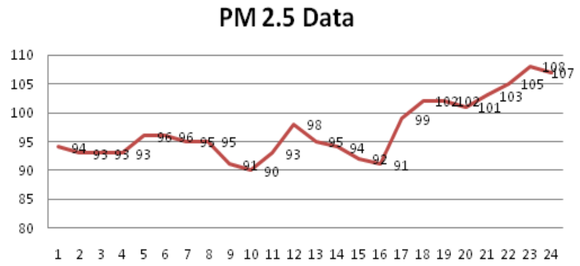

Figure 8. Real-time values of PM 2.5

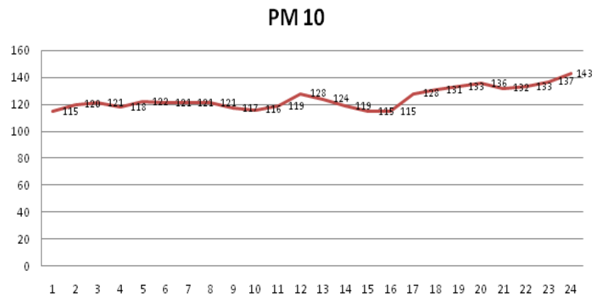

Figure 9. Real-time values of PM 10

The readings transmitted to ThingSpeak server are shown in Figure 10.

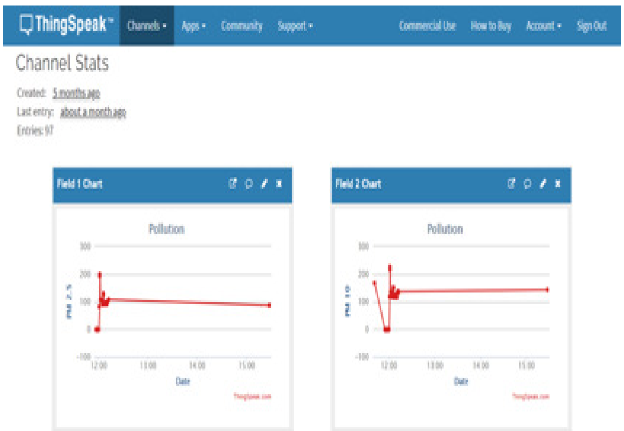

Figure 10. PM 25 and PM 10 Readings on ThingSpeak Server

V. Conclusion

This project aimed to implement IoT based system using UAV and has specific features such as air pollution measurement and live streaming. This sytem is able to measure parameters of air pollution such as PM 10 and PM 2.5. The data collected from these sensors is stored in IoT based cloud platform directly with the ThingSpeak server. By doing so we were able to obtain the data in real-time and stored it for further analysis. The UAV hovered at various points of interest in the city and the level of air pollution was known in real-time.

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