ENVIRONMENTAL AIR QUALITY MONITORING SYSTEM AS A SUPPORT FOR PRECISION AGRICULTURE

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Abstract: *In order to make better decisions in the precision agriculture the measurement of air pollution parameters such as PM10, NOx, SO2, CO, O3 and agriculture parameters such as air temperature, humidity, soil moisture and leaf wetness are of crucial importance. Making analysis using different AI technics based on these parameters can bring better yield and quality in the food production process. In this paper, we present our approach in building an environmental air quality monitoring system as a support for precision agriculture by using Arduino [5] open-source electronics platform.*

Keywords: AIR POLLUTION, ARDUINO OPEN-SOURCE ELECTRONICS PLATFORM, WSN, IoT

1. Introduction

Rapid development of IoT technologies made an impact in production of more accurate and cost effective sensors. Application of wireless sensor networks (WSN) yields a great benefit in agriculture and the food production process. Farmers and companies are able to make more precise decisions based on measurements taken from the wireless sensor network. On the other hand pollution data are very important for quality food production, but sensors for environmental measurement have to be very accurate but not very expensive.

For agriculture parameters we designed a wireless sensor network that is cost effective, easy to scale and has efficient power consumption management [1]. Sensor node, which is the smallest structural and functional unit of our wireless sensor network, is equipped with multiple sensors for measuring important environmental parameters in the field of agriculture. Environmental air quality monitoring system as a support for precision agriculture is equipped with multiple sensors for measuring pollution parameters and also is cost effective.

This paper is organized as follows. Section 2 gives an overview of the monitoring system with wireless sensor network, while in section 3 we present architecture of WSN sensor node structure for agriculture upgraded with pollution sensors by using Arduino open-source electronics platform. In section 4 we present our cloud services for data collection and visualization for further analysis. Section 5 concludes the paper and presents the future work.

2. Overview of the monitoring system for agriculture

The wireless sensor network for agriculture is constructed from sensor nodes (A1, A2, A3…An) and base stations (Fig.1). It uses a star-of-stars network topology, where every sensor node sends its data directly to the base station. Long range communication protocol (LoRaWAN) [2] [4] that we use for data transmission, dictates this kind of topology. This gives us the benefit of easy and inexpensive network scalability, while maintaining the possibility of placing our sensor nodes at a great distance from the base station. Packets that are received from the base stations are then send via the TTN (The Things Network) IoT platform to our cloud services. The wireless sensor network for pollution monitoring system is constructed from sensor nodes for pollution parameters (P1,P2,P3..Pn) and base stations. Communication protocol is constructed with SIMCOM 800I.

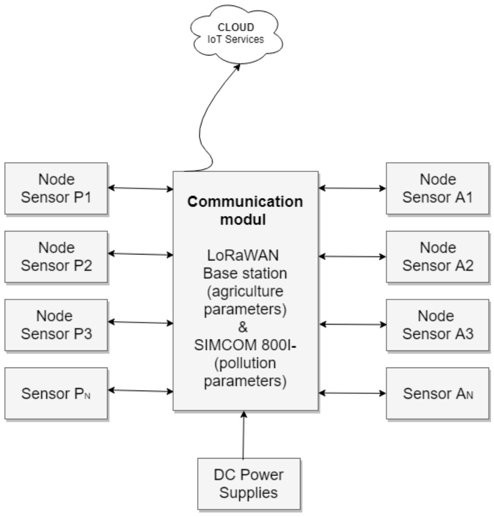

Fig. 1. *Wireless sensor network topology diagram*

On the other hand the wireless sensor network for pollution monitoring system is constructed from sensor nodes for pollution parameters. We have two options:

1. Cost effective sensor nodes with PMS5003- PM Sensor - PLANTOWER(R) (for PPM concentrations) and

2. Alphasense(R) 4-electrode sensors with low power, validated technology for use in high volume applications and evolving markets such as Air Quality monitoring. This type of sensors are specifically designed for low gas concentration detection: parts per billion (PPB). (Fig.2)

Fig. 2. *Alphasense 4-electrode sensors*

3.Architecture of upgraded wireless sensor network for agriculture

The sensor node is the smallest structural and functional unit of our WSN. Every sensor node should be equipped with all necessary sensors, processing unit for collecting, processing and encoding the data from the sensors, as well as communication module for sending the data to the backend service for further analysis. Every solution to this problem has its trade-offs in terms of cost and efficiency. Nevertheless every solution must fulfill certain requirements i.e. collection of accurate data, efficient power consumption, easy and economical network scalability and reasonable overall system construction and implementation cost.

In our solution the sensor node for agriculture is an isolated unit i.e. it does not communicate or share data with other nodes. The sensor node gathers the measurements from its own sensors, process and encodes the data and transmits it to the data collection service. It consists of three different sensors, microcontroller as a processing unit and LoRaWAN communication module for data transmission. The sensor node is equipped with sensors for measuring air temperature, air humidity, leaf wetness and soil moisture. These parameters are very important for further data analysis and extraction of valuable knowledge that cannot be observed from the raw data that we collect. As we said earlier, that we need to maintain reasonable overall system cost, for measuring of air temperature and humidity we chose to implement DHT22 sensor in our sensor node. DHT22 in comparison to other sensors on the market has a great balance between the performance and accuracy of the sensor and its cost. For sensing the leaf wetness of the plants we used the standard "wired leaf wetness sensor". These sensors are inexpensive, but most of them need to be calibrated for accurate measurements before use (Fig.3). For measuring the soil moisture, we used the standard soil moisture sensor with two probes. This sensor measuring process is very similar to the leaf wetness sensor and for that reason it also needs calibration before use. The leaf wetness sensor and the soil moisture sensor need additional LM393 chip for analog to digital conversion of the sensed measurements.

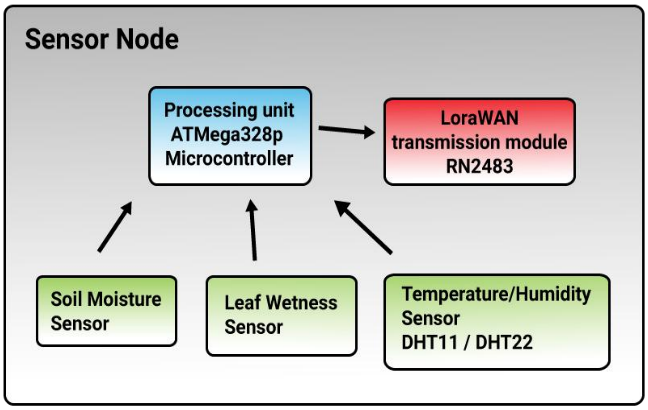

Fig. *3* Sensor node structure diagram for agriculture parameters

In our sensor node as a processing unit we use ATMega328p microcontroller [3]. This microcontroller is famous for its integration in the Arduino open-source electronics platform [5]. Because of its fame there are many libraries that help in easy integration with other modules and sensors. Its low cost and great performance in terms of power consumption and processing power, make this microcontroller acceptable for this application.

The purpose of the microcontroller is coordination of the sensor node i.e. to collect, transform and encode the data from the sensors, activate and connect the transmission module with the network base station and send the data to data collection service. Usage of this Wireless Sensor Network requires that the sensor nodes need to be placed in an open field without external power supply i.e. every sensor node must operate on battery power supply. Running on battery power supply adds a challenge on the overall sensor node inner workings design for power efficiency.

Parameters that we need to monitor with this system do not have real time constraint (e.g. air temperature and humidity cannot change in a second). For this reason we designed our system to work in cycles i.e. to take measurements every 18 minutes for 5 seconds runtime.

In our solution for Air quality monitoring system, the sensor node for pollution parameters is also constructed with Arduino open-source electronics platform (Fig.4). In this case is very important to know which pollution parameters we need to measure. If we have land near the roads and factories, then we have to measure NOx, PM, O3, CO and SO2 (in this case we will use Alphasense sensors, Fig. 2). On the other hand we will measure only PM parameters (cost effective).

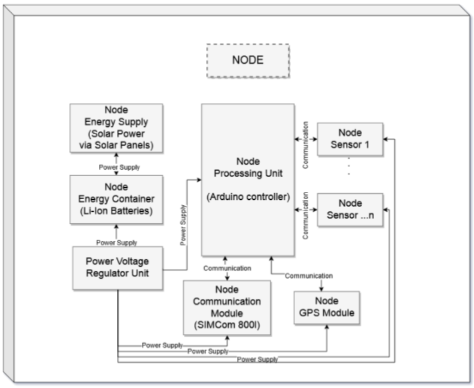

Fig. 4 *Sensor node structure diagram for pollution parameters*

4. Data acquisition and visualization services

We developed two services for the purpose of collection, storage, filtering and formatting of the data from the wireless sensor network. Main purpose of this service is to accept and store the incoming data from the TTN platform i.e. our sensor nodes. This application was developed using the Java EE technology. Collected data is then transferred to the data warehouse using ETL (extract, transform and load) software, to be utilized by our other services. Additionally in our data warehouse we store weather prediction data from our HPC weather prediction software for future comparison and data analysis. General purpose of the data visualization service is to supply the data from the data warehouse in a certain format so it can be easily adapted to a specific visualization type. The data can be visualized in many forms: charts, plots, maps and tables. To adapt the data for a certain format it needs to be filtered and formatted based on certain conditions and visualization types. Filtering conditions are based on certain property or properties (e.g. temperature, humidity, etc.) with specified marginal values, as well as the time period that needs to be observed. In addition to the data collection and visualization services, we developed a web interface for remote monitoring of the data from the wireless sensor network as well as overviewing the data in a different visualization types such as charts, plots, maps and tables. The web application was develop in AngularJS as a single page application (SPA) and D3 library for the different visualization types.

5. Conclusion

In this paper we presented an overview of our environmental Air quality monitoring system as a support for Precision Agriculture. Also we present structure and topology of wireless sensor network. We presented its smallest structural and functional unit i.e., the sensor node. We presented the data transmission protocol that we used and its tradeoffs, as well as our data collection and visualization services that collect, store, filter and format the data from the wireless sensor network.

For the future work we intend to extend our cloud services i.e. to create two more services, one for the data analysis and the other one for decision support. Making analysis using different AI techniques based on these parameters can bring better yield and quality in the food production process. The data analysis service will use prediction models and data mining techniques for forecasting the emergence of a certain disease (infection), as well as presenting the marginal values for optimal quality of the product. The decision support service will help the user in the decision making process such as application of pesticides and irrigation.

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