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Smart Indoor Air Quality Monitoring System

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Abstract- Temperature, humidity, PM 2.5, and formaldehyde are just a few of the air quality factors that may be measured in real-time by a low-cost system that utilizes LoRa technology. A star topology is used in the system's architecture, with sensor nodes linked to a routing node that is linked to a gateway node. The sensor nodes are built using inexpensive, commercially available sensors that are connected to a microcontroller. The sensor data is sent to the routing node, which is also built using a low-cost microcontroller (like Raspberry Pi), using a LoRa hat module SX1262. The gateway device stores, displays, and processes data using a time-series database and a server. A transmission range of around 3 km with no packet loss and 4 km with 20% packet loss may be accomplished using LoRa technology.

Index Terms—air quality monitoring, LoRa, PM 2.5, formalde- hyde, Raspberry Pi.

I. INTRODUCTION

The air we breathe has become more polluted due to the increased development of infrastructure, the exponential rise of automobiles on the road, and the fast industrialization of our society. The number of cases of asthma, bronchitis, and other respiratory illnesses has increased dramatically as a result of this. The government and administration have taken several steps to reduce air pollution and enhance air quality as part of the smart city initiative. The first stage in accomplishing this objective is to assess the air quality at several points around the city in a precise and timely manner. There are a number of cities in India that have air quality monitoring facilities, and they are all somewhat big and expensive to set up and keep running. on addition, the air quality data is kept on centralized systems and is not always accessible to the public. Several low-cost air quality monitoring systems have been implemented in recent years, thanks to the development of wireless sensor networks (WSNs) and the Internet of Things (IoT). While there is a proposal for a portable air-quality monitoring node that can detect ozone levels using Bluetooth and GPS, the data rate and communication range are severely constrained in this device [1]. Although WiFi provides far faster data rates and greater capacity, it is more costly and requires an internet connection at all times, which may not be available in rural regions. Low Power Wide Area Network (LPWAN) technologies enable the interconnection of devices with limited bandwidth and battery power across vast distances (3-5 km) at high data rates (1-5 kbps) independent of an internet connection. These services are provided by a number of modern technologies, such as SigFox, NB-IoT, LTE M, LoRa/LoRaWAN by Semtech, and others. Their primary operating frequency is the unlicensed sub-1 GHz range, which includes 433 MHz and 868 MHz. Lots of new Internet of Things (IoT) applications using LoRa technology have been popping up recently in areas like smart grid [9], smart healthcare [10], air quality monitoring [7], structural health monitoring [8], etc.

We show how to use LoRa technology to create a cheap system that can monitor the air quality inside and outside in this article. Semtech's LoRa and LoRaWAN are the most popular low-power wide-area network (LPWAN) technologies, and they come with a variety of commercially available modules and hats. Our setup has shown sensor data transmission up to 3 km with 100%

packet reception using a LoRa hat module layered over a normal Raspberry Pi. Part II: The Architecture of the System We used commercially available, pre-calibrated sensors to track the air quality both inside and outside. For this project, we choose to use the following sensors: DHT22 for temperature and humidity, DSM501A for PM2.5, Grove HCHO for formaldehyde, and MG811 for CO. These sensors are ideal for widespread use due to their cheap cost, low power consumption, and easy availability.

The standard sensors and air CO2 levels were used for calibration purposes to ensure that their output was accurate. In [2], a WiFi-enabled smart sensor network is set up to monitor the air quality inside a building. From [3] to [6,] many additional systems using commercially available sensors and microcontrollers (such as STM32, Arduino, and Raspberry Pi) have been suggested. When it comes to connecting the sensor node to the cloud server, the majority of the solutions that have been suggested have relied on either WiFi or Bluetooth. Two aspects make up the system architecture; first, a microcontroller with an integrated WiFi module (like NodeMCU) was used to interface the sensors directly; second, data visualization was done on a third-party cloud platform (like Thingspeak).

Figure 1 is a picture of the actual system that was created, and Figure 2 is the interface that shows the real-time data on the cloud platform. While this method is simple to implement, it does have a few major drawbacks. Firstly, it can only be used in areas with WiFi connectivity, as data is transmitted directly from the sensor node to the cloud over WiFi. Secondly, there is a noticeable delay in the visualization of real-time data due to the 15-second refresh time of the cloud server.

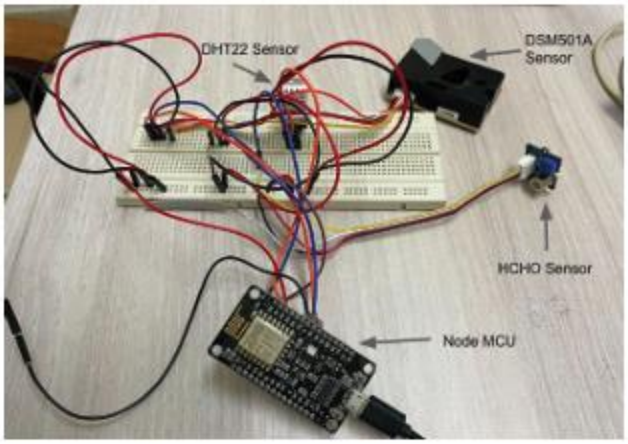

Fig. 1: Air quality monitoring system implemented using NodeMCU

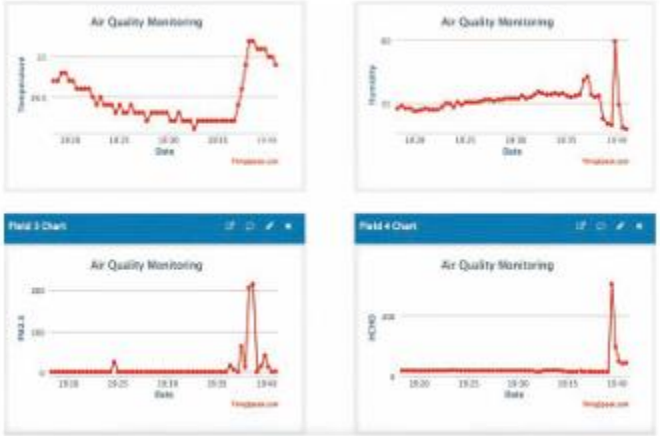

Fig. 2: Results of the implemented air quality monitoring system as seen on the ThingSpeak platform data.

Very little was changed to the suggested system architecture in order to get around these restrictions. A LoRa HAT module (Waveshare SX 1268) was layered on top of a Raspberry Pi in the updated design, allowing sensors to communicate without WiFi. This LoRa module uses the Semtech SX1268 chipset and operates at sub-1 GHz for radio frequency transceivers. It transmits data from sensors in an IoT network using the unlicensed 433 MHz spectrum. The increased communication range and reduced bandwidth provided by this technology were the main factors in choosing this module. In Fig. 3, we can see the updated system design in action, together with the transmitter and receiver.

Without a WiFi or cellular internet connection, the data transfer is clearly occurring over the 433 MHz range.

II. RESULTS AND DISCUSSIONS

The developed system was tested using a star-of-stars network architecture, as seen in Figures 4 and 5. Three sensor nodes served as transmitters, while one node acted as where the gateway node is relayed via a single router that is linked to three sensor nodes. The edge device that stores and displays the sensor data is the gateway node.

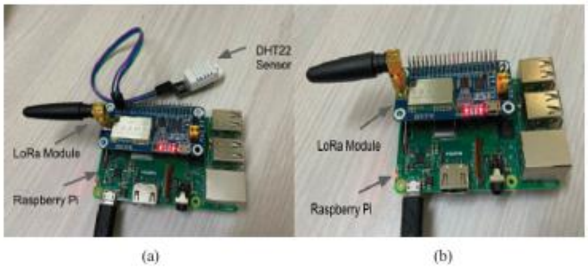

Fig. 3: (a) Transmitter node and (b) Receiver node imple- mented using a Raspberry Pi and LoRa module

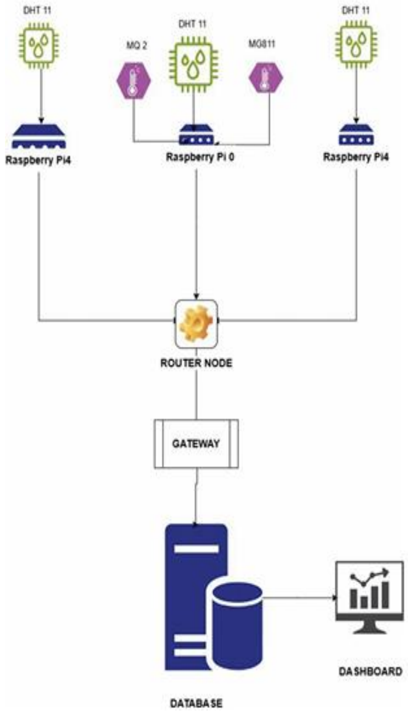

Fig. 4: Block diagram of the proposed system design

Fig. 5: Photograph of the actual setup mimicking the topology shown in Fig. 4

another one to act as the doorway. Zero, Pico, and 3B+ microprocessor boards from the Raspberry Pi series were used to implement all of these nodes. There were two groups that conducted the tests: the range test and the network test. In all of these tests, the planned system's performance was evaluated by counting the number of packets that were successfully received by the receiver. Despite the close proximity of the transmitter and receiver, the number of correctly received packets was found to be quite low in the first testing. The primary cause of this was the packets transmitted by the two transmitters colliding on the same channel. In response to this difficulty, the receiver included a buffer to temporarily retain node data before sending it to the cloud. In the event that the gateway is temporarily unable to upload the data, this will nevertheless guarantee that the network will communicate all captured data to the cloud in due course. Even during times of peak network traffic, the network can keep data delivery constant and dependable by temporarily keeping it in the buffer. The Range Test (A) The capacity to communicate across great distances is one of the main selling points of LPWAN technology. The receiving LoRa node was mounted on an electric pole beside the highway, while the sending nodes were transported in a car, in order to gauge the potential communication range of this equipment. Up to a distance of 3 km, it was observed that all packets were successfully received. Unfortunately, this was limited to LoS communication only, and packet loss might occur due to physical barriers like trees. As seen in Figure 6, packet loss became noticeable at 3 km, and by 4.7 km, only 20% of packets were successfully received. As a result, the established LoS communication range Operating at 3 km, which is lower than the 5 km stated in the datasheet for the SX 1268 LoRa module. Unit B: Network Evaluation The resilience of the developed network was evaluated in the second test, which was conducted within the lab. In this setup, the sensor nodes would all use LoRa to send data to the router, which would then relay that data to the gateway. The data storage and visualization configuration was deployed on the gateway node, which was configured as an edge computing device. To get around the cloud platform's refresh time lag, we built a local server using the NodeRed platform and sent data to an InfluxDB-powered time-series database. After receiving data from the routing node, a straightforward flow was developed to process and format it according to the specifications of the InfulxDB REST API. The data was then sent to the database for storage. A local server and database were created at the receiving gateway once the whole configuration was deployed. In addition, all the sensor nodes' recorded air quality data was efficiently shown by creating a basic dashboard using Grafana. Visualization of the air quality data from all the sensor nodes is possible, as seen in Figure 7. We saw no packet loss from any of the sensor nodes throughout our extensive testing of the configuration, and we can now monitor the data in real-time.

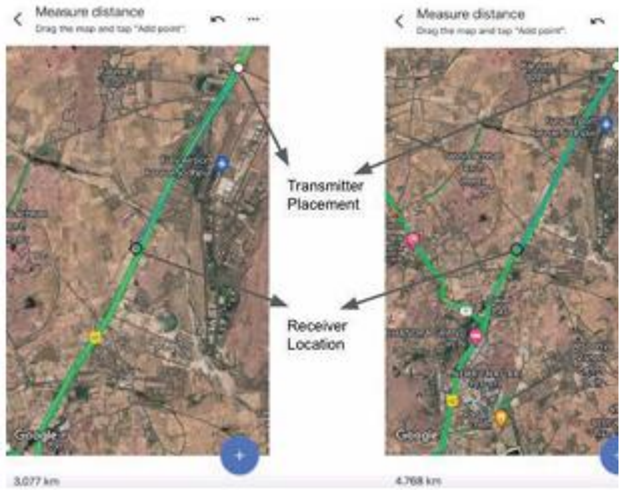

Fig. 6: Picture of the maps showing the achieved communica- tion range for 100% data reception and 20% data reception.

III. CONCLUSIONS

Using LoRa technology over Raspberry Pi, an inexpensive and real-time internet of things (IoT) system was set up to monitor the air quality. Without an internet connection, a battery-powered gadget can monitor air quality indicators as PM2.5, VOC, temperature, and humidity for up to 3 km. It has been shown that the used system

Fig. 7: Screenshot of the dashboard created to visualize the data received from all the transmitter nodes.

It may be used for keeping tabs on the natural conditions in far-flung areas that are crucial to the military and defense.

REFERENCES

1. P. Vo¨lgyesi, A. Na´das, X. Koutsoukos, and A´. Le´deczi, "Air quality monitoring with sensormap," in 2008 International Conference on Information Processing in Sensor Networks (ipsn 2008). IEEE, 2008, pp. 529–530.
2. O. A. Postolache, J. D. Pereira, and P. S. Girao, "Smart sensors network for air quality monitoring applications," IEEE transactions on instrumentation and measurement, vol. 58, no. 9, pp. 3253–3262, 2009.
3. M. B. Marinov, I. Topalov, E. Gieva, and G. Nikolov, "Air quality monitoring in urban environments," in 2016 39th International Spring Seminar on Electronics Technology (ISSE). IEEE, 2016, pp. 443–448.
4. S. Devarakonda, P. Sevusu, H. Liu, R. Liu, L. Iftode, and B. Nath, "Real- time air quality monitoring through mobile sensing in metropolitan areas," in Proceedings of the 2nd ACM SIGKDD international workshop on urban computing, 2013, pp. 1–8.
5. S. Kumar and A. Jasuja, "Air quality monitoring system based on iot using raspberry pi," in 2017 International conference on computing, communication and automation (ICCCA). IEEE, 2017, pp. 1341–1346.
6. J.-H. Liu, Y.-F. Chen, T.-S. Lin, D.-W. Lai, T.-H. Wen, C.-H. Sun, J.-Y. Juang, and J.-A. Jiang, "Developed urban air quality monitoring system based on wireless sensor networks," in 2011 Fifth International Conference on Sensing Technology. IEEE, 2011, pp. 549–554.
7. K. Zheng, S. Zhao, Z. Yang, X. Xiong, and W. Xiang, "Design and implementation of lpwa-based air quality monitoring system," IEEE Access, vol. 4, pp. 3238–3245, 2016.
8. A. Moallemi, A. Burrello, D. Brunelli, and L. Benini, "Exploring scalable, distributed real-time anomaly detection for bridge health mon- itoring," IEEE Internet of Things Journal, vol. 9, no. 18, pp. 17 660– 17 674, 2022.
9. Z. Wu, M. Zhu, Q. Li, L. Xue, J. Yang, Z. Chen, Y. Cao, and Y. Cui, "Design of power monitoring system for new energy grid-connected operation based on lora and 4g technology," Energy Reports, vol. 8, pp. 95–105, 2022.
10. J. Kharel, H. T. Reda, and S. Y. Shin, "Fog computing-based smart health monitoring system deploying lora wireless communication," IETE Technical Review, vol. 36, no. 1, pp. 69–82, 2019.