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IoT enabled Environmental Air Pollution Monitoring and Rerouting system using Machine learning algorithms

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Abstract: Massive Internet of Things (IoT) is foretold to introduce surfeit of applications for a fully connected world. The increasingly degrading quality of air in several regions of the biosphere can be a reliable impact of human difficulties of increasing globalization and urbanization. Air pollution levels in many cities exceed legal and World Health Organization (WHO) limits for particulate matter and gaseous pollutants which can be found in concentrations that are hazardous to health. Regular acquaintance to high pollution intensities results in increase of humans affected from respiratory disorders such as asthma, chronic obstructive lung disease and increased mortality. In most of the cities, there is no chance for peoples to apprehend the levels of pollution they are undergoing in their day-to-day lives which is necessary to reduce their risks from poor air quality conditions. The quality of air can be measured by using a parameter named Air quality index. The Key pollutants to calculate Air quality index are particulate matter (PM2.5 and PM10), Ozone (O3), Nitrogen Dioxide (NO2), Sulphur Dioxide (SO2) and Carbon Monoxide (CO). This work deliberates the implementation of cloud based IoT system for air quality monitoring in which the sensors are used to calculate CO, PM2.5 and PM10, O3, SO2 and NOx pollution level with environmental condition like temperature and humidity. The obtained information can be updated in cloud platform using Lora nodes and Lora Gateway. The web-based application developed has a Google map API where the pollution status can be frequently updated. With the collected time series samples, the prediction analysis was done for PM with neural network Multi-Layer perceptron and support vector machine regression (SVMR) learning algorithm. This can helps a person to travel to any other places by automatically rerouting conditions in a pollution free environment.

1. Introduction

A quarter of India's population is exposed to air pollution levels which is a major cause of serious health issue. Air Pollution is a mixture of solid particle and gases in the air which occurs when some harmful for additive quantities of substances are introduced in Earth's atmosphere. The release of pollutants into the air can be made from car emissions, chemicals from factories, dusts, pollens and mould spores. Air pollution in the form of carbon monoxide and methane raises the earth temperature. Few of the air pollutants are hazardous and can have several health risks even in small amounts. The ambient air quality measurement in India can be determined by air quality index (AQI) which translates numerical data into a descriptive rating scale and makes it easier for citizens of all ages to understand the level of pollution in the air they breathe. The Air Quality Index is based on measurement of particulate matter (PM2.5 and PM10), Ozone (O3), Nitrogen Dioxide (NO2), Sulphur Dioxide (SO2) and Carbon Monoxide (CO) emissions [1]. An air quality index is a scale used to show how polluted the air is, along with the risks associated with each rating. An AQI is calculated based on medical research for the acceptable levels of major air pollutants to inform the public about air quality in an comprehensible manner so that they may take action to protect their health and to help countries develop and assess policies for better air quality.

Particulate Matter (PM2.5 and PM10) contains little, strong particles that frequently originate from traffic and ignition. These particles infiltrate aviation routes, lungs and even veins. They are known to be liable for cardiovascular and respiratory ailments, just as lung tumours. Nitrogen dioxide (NO2) is a stifling and aggravating gas that comes for the most part from ignition. In high focuses it is known to cause bronchitis, asthma and other respiratory ailments. Ozone (O3) is a gas framed by a compound response between different contaminations. Its fixation is high when there's a blend of solid daylight and high groupings of nitrogen dioxide from burning. It is known to be answerable for respiratory and heart ailments, asthma and eye bothering.

To decide air quality in a zone, contamination fixations are truly estimated and detailed. The AQI is determined dependent on the normal centralization of a specific toxin estimated over a standard time span (24 hours for most poisons, 8 hours for carbon monoxide and ozone). For instance, the AQI for PM2.5 depends on 24-hour normal fixation and processed.

Table 1: AQI Category, Pollutant Level and Health Break Points.

AQI Category (Range)	PM_{10} (24hr)	$PM_{2.5}$ (24hr)	NO_2 (24hr)	O_3 (8hr)	CO (8hr)	SO_2 (24hr)
Good (0–50)	0–50	0–30	0–40	0–50	0–1.0	0–40
Satisfactory (51–100)	51–100	31–60	41–80	51–100	1.1–2.0	41–80
Moderately polluted (101–200)	101–250	61–90	81–180	101–168	2.1–10	81–380
Poor (201–300)	251–350	91–120	181–280	169–208	10–17	381–800
Very poor (301–400)	351–430	121–250	281–400	209–748	17–34	801–1600
Severe (401–500)	430+	250+	400+	748+	34+	1600+

Good AQI denotes the range from 0 to 50 me and it represents there is no contamination of air. Satisfactory AQI denotes the range from 51 to 100 in which the sensitive people should consider reducing prolonged or heavy outdoor exertion. Moderately polluted AQI denotes the range from 101 to 200 and it is unhealthy for sensitive groups. People with lung disease, children and heart disease should limit prolonged exertion. Poor AQI denotes the range from 201 to 300 in which the peoples with lung disease, children's and older adults, people who are active outdoors, people with certain genetic variance and people with diet limited in certain nutrients should avoid all outdoor exertion. Very poor and severe AQI where is from 301 to 500 in which everyone should avoid all physical activity outdoors. Peoples with heart and lung disease, children's, and all the peoples with some medical constraints should remind windows and keep activity levels low.

The estimation of air quality index for a normal person is found to be very difficult. When a person has to travel from one point to another point he has to cross several major cities. The pollution level in many of the cities is increasing day by day and if the person has to take a travel through non polluted area, it will be very difficult for him to estimate the hour quality index value for different area [2]. In order to make him travel through a list polluted area an IoT enabled environmental air pollution monitoring and rerouting system has been proposed in this work with a machine learning algorithm in order to view all the pollution level in Google maps and automatically update the best possible route with least polluted area.

The rest of the paper is structured as follow. Section 2 describes the related work in which the different air pollution monitoring schemes are discussed. Section 3 describes the proposed model in which the air pollution is monitored and web based application has developed with Google map API in which the pollution status can be frequently updated and a rerouting can be done by using a neural network with multilayer perceptron and support vector machine regression learning algorithm. Section 4 describes about the results and conclusions.

2. Related Work

Air pollution monitoring unit has been developed with the help of wireless sensor network and this sensor network gives the information about the pollution level of a certain area by using a centralised server to internet for any telecom network. In this work carbon monoxide and other pollutant gas level is measured in the form of PPM and it is transmitted through GPRS and the location is transmitter using global positioning system. The collected data through the sensor will be converted into a digital format and transmitted by any network can be represented on http link and create an APK file application presentation of this data [3]. Sequential modelling framework has been proposed in order to monitor and predict the air pollution status which has been caused due to rapid urbanization. In this framework the air quality is measured by estimating the values of particulate matter and nitrogen dioxide using wireless sensor network and the prediction of air pollution is done by using the historical air quality and meteorological data [4].

Monitoring and controlling of air pollution in an urban area is done by creating architecture for intelligent pollution prediction and visualisation. The step-by-step modelled architecture includes creation of architecture to find the pollutant and its level, the system is built by constructing a kriging interpolated pollutant field for the observed pollutant. The updating the polluted data can be forecasted by using recurrent neural network with long short term memory. Finally the prediction can be made for the future and the server returns the information about the alarming thresholds [5]. Spatiotemporal correlation between air and noise pollution has been investigated in this work can be able to monitor the air pollution level and update the real time values in maps and forecast the pollution levels. This study also evaluates the variation in air pollution due to different factors such as crowd movement, changing in traffic, vehicle movements and due to the operation of many industries [6].

The prediction of urban air pollution is achieved based on convolution recurrent neural networks. The first step of this scheme is to determine the transboundary air pollution by using a dynamic method and the second step involves the training process by constructing the instances from local atmospheric monitoring data and transboundary air pollution data [7]. Air quality sensors are used to determine the pollution levels present in air which is caused by industrial plants, smog and emission from car and trucks. The indoor air pollution may also be calculated because of the usage of pesticides, particulate matter, biomass smoke, fire places and environmental tobacco smoke. When the pollution level exceeds the threshold level and alert can be transmitted to the nearby uses by using their existing telecom network or through any Wi-Fi network [8].

Urban air pollution monitoring system with forecasting models studied in this literature work are equipped with an array of gaseous and meteorological low cost sensors and communicate the information wirelessly. This information transmitted will be stored pre-processed and convert the data into a useful information for forecasting the pollution based on the historical information. Using multivariate modelling scheme the prediction accuracy has been enhanced and the error rate has been reduced because of the dependency between target gases and other features [9]. The keep pollutant generated from carbon monoxide, oxides of nitrogen and particulate matter are calculated by using the sensors deployed in roadside and it is communicated by using Lora WAN network [10]. The gateway used in this network obtains the information from different nodes with the collected time series sample and the prediction analysis was done with neural network multilayer perceptron and support vector machine regression algorithm [11].

In this literature the air quality assessment has been done based on the images obtained from satellite using supervised machine learning techniques. K nearest neighbour and gradient boosting technique is used to predict the air quality index based upon the historical images which are fed through the system [12]. Air quality index forecasting is performed using parallel dense neural network and LSTM cell. In this technique the hair solution updates can be done using a sensor network and by using the present values in air quality index and historical values of air quality index the pollution level is predicted [13]. In smart cities the narrow band IoT network has been deployed for collecting the data from different type of sensors which is deployed in the field to calculate the air pollution. The information obtained through the narrow band IoT network is processed and the air quality index value is estimated and transmitted through any mobile broadband network [1].

3. Design and Implementation

The air pollution in a roadside environment is increasing day by day and it causes inconvenience of the passengers during their travel with few health issues according to their body conditions. In order to avoid their travel through a polluted environment, a low cost wireless air pollution monitoring system was developed in this work as mentioned in Figure 1 to measure the levels of polluted gases and update the information in Google maps which can help the passengers to reroute their journey based on low polluted area. The work has three parts in which the first part deals with the hardware components and the second part deals with the software component that is updating in

Google maps and third part deals with the rerouting system which can able to reroute travel based on least polluted area.

3.1 System Architecture

The Air Quality is based on measurement of particulate matter (PM2.5 and PM10), Ozone (O3), Nitrogen Dioxide (NO2), Sulphur Dioxide (SO2) and Carbon Monoxide (CO) emissions.

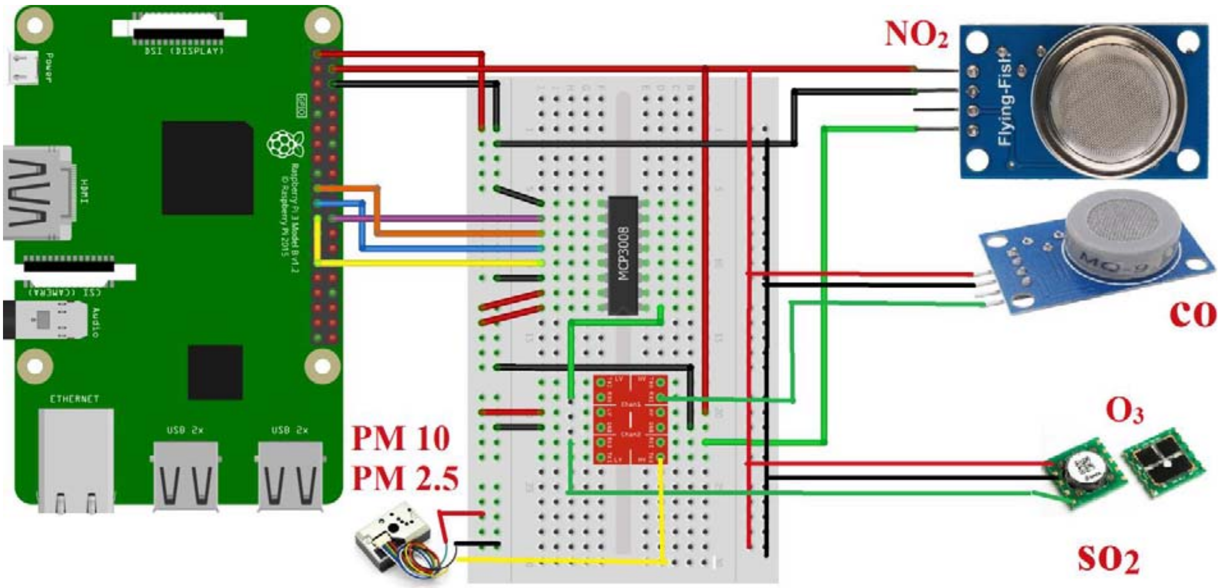

Figure 1. System model with interfacing all sensors

The air is polluted by different mixture of small particles with a diameter less than 10µm and this refers to a term called particulate matter. This is of most concern because the particles with a diameter of less than 10 µm can be inhaled by a human being and enters into the lungs which cause serious health effects. This can be measured by an optical dust sensor module which transcends the dust particles in air by the transmission of light. In this sensor light transmitted in air and this light gets reflected refracted and scattered bite the dust particles present in the air. Depending upon the measure of scattering property, reflective index and absorption of light the particle count can be measured and the size of particles can be estimated. Ozone is a colourless and highly irritating gas and this considered as a secondary pollutant that is formed when the pollutant emitted by car, power plant, industrial boilers and other resources react chemically in presence of sunlight. MQ131 Ozone Sensor detects and measures Ozone (03) Concentration from 10ppb to 2ppm which is ideal for monitoring air quality or for use in environment and research experiments.

Oxides of nitrogen are mixed in the air from the emissions of car trucks buses power plants and due to the burning of fuels. Breathing and with the high concentration of nitrous oxide can cause some respiratory diseases which leads to wheezing and asthma problems. Carbon monoxide is a poisonous gas which is produced due to burning of gasoline, wood, propane, charcoal and other fuels. Breathing carbon monoxide regularly can cause many uncomfortness in human body and death may occur if the humans are exposed to higher levels. MQ7 is low cost sensor which can be able to measure the concentration of carbon monoxide in air. Due to the burning of coal and oil in power plants Sulphur dioxide is released in the air. This can also be emitted from trains, large ships and some diesel equipment’s that burns high

Sulphur fuel. When if humans are exposed in such air pollution the respiratory system may be affected and causes irritation to the eyes. 110-602 Sulphur dioxide electrochemical sensors can be used to you send the amount of gas mixed with air and it provides easy integration into wireless solution.

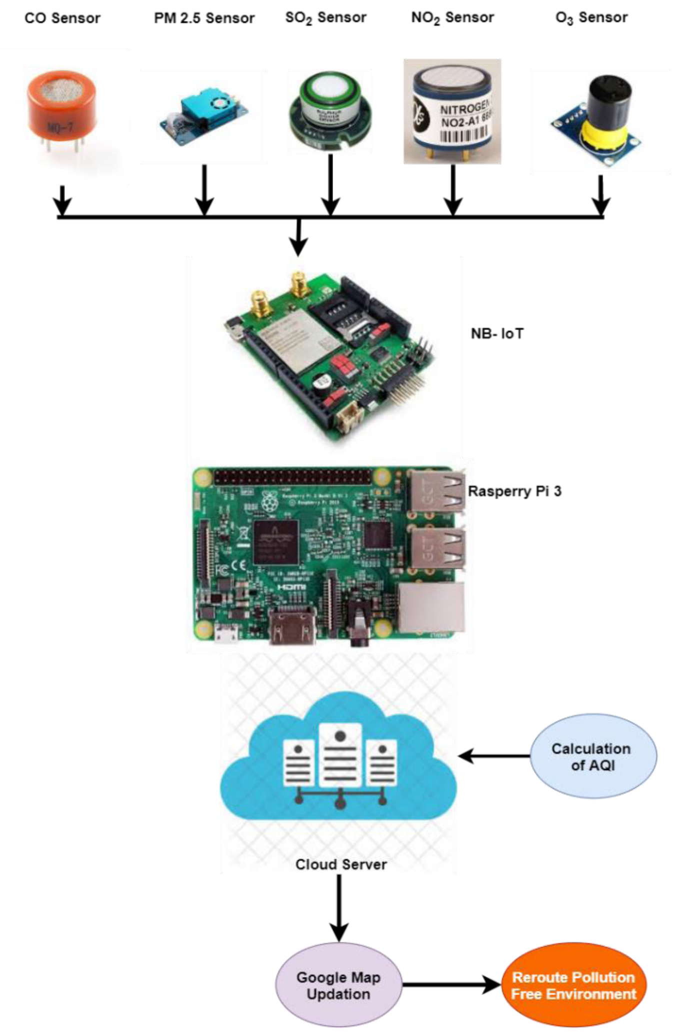

Figure 2. Flow diagram for Environmental Air Pollution Monitoring and Rerouting system

3.2 NB-IoT Transmission Module

Most of the air pollution is man-made and derived from the poor combustion of fossil or biomass is experienced by the population living in and around urban areas. Narrowband IoT (NB-IoT) is a suitable Technology that is based on 4G LTE networks uses the same infrastructure to connect to the network. The information obtained through the different types of sensors is transmitted to the network by using the narrow band device. NB-IoT is low power wide area networking Technology that is developed to enable efficient communication by providing much wider coverage with long battery life and lower cost.

3.3 Processing of data

The data from narrow band IoT devices transmitted via an LTE network along with OFDMA and SCFDMA signal waveforms in downlink and uplink respectively. The data received from NB-IoT is highly unstructured and it is very difficult to analyse the obtained data. WISE-4000 wireless sensor node support MQTT open communication protocol in which Users can transmit data to specific public cloud services or existing private cloud platforms. By pre-integration with MQTT protocol, NB-IoT nodes can integrate with cloud services automatically, reducing setup complexity for rapidly implementation. Figure 2 shown below explains the process of environmental air pollution monitoring and rerouting system. The information transmitted through a NB-IoT device is transmitted to some specific public cloud service. The air quality index value should be estimated from the data obtained from particulate matter sensor, nitrous oxide sensor, carbon monoxide sensor, ozone sensor and Sulphur dioxide sensor. The Air quality index value depends on the amount of gas that is mixed in in the atmosphere.

In numbers, AQI is represented between 0 to 500 with 0 representing good air and 500 representing hazardous air. The AQI is calculated based on the average concentration of a particular pollutant measured over a standard time interval (24 hours for most pollutants, 8 hours for carbon monoxide and ozone). For example, the AQI for PM2.5 is based on 24-hour average concentration and computed. The goal of an AQI is to rapidly scatter air quality data (nearly progressive) that involves the framework to represent contamination's which have momentary effects. It is similarly significant that the majority of these toxins are estimated persistently through a web based observing system. An example of AQI calculation and description for Coimbatore (online air quality monitoring network) is presented here. The sub-index (Ip) for a given pollutant concentration (Cp), as based on 'linear segmented principle' is calculated as:

$$I_{p=} [\{(I_{HI} - I_{LO})/ (B_{HI} - B_{LO})\} * (C_p - B_{LO})] + I_{LO}$$

B_{HI}= Break point concentration greater or equal to given conc.

B_{LO}= Break point concentration smaller or equal to given conc.

I_{HI} = AQI value corresponding to B_{HI}

I_{LO} = AQI value corresponding to B_{LO}

The AQI framework ought to have web-based AQI spread which ought to be intended for online count and show of across the nation AQI. The website should deliver a snappy, straightforward and an exquisite looking reaction to an AQI inquiry. The other features of the website should include reporting of pollutant responsible for index, pollutants exceeding the standards and health effects.

3.4 Updation in Google maps and Rerouting

The estimated air quality index from each area is updated in google maps using an API from Google map. To suggest an alternative route for the passengers the location of the particular point and the distance of the routes where considered. For example if a person has to travel different place which has a moderate air quality index, then the optimal distance for the moderate AQI and good AQI will be estimated and depending upon the passengers convenience the routes can be selected with moderate AQI or good AQI. If the Current route is moderate, then it will check the optimal distance based on data[i].dist < maxDistance and data[i].dist - minDistance < C, where C is constant.

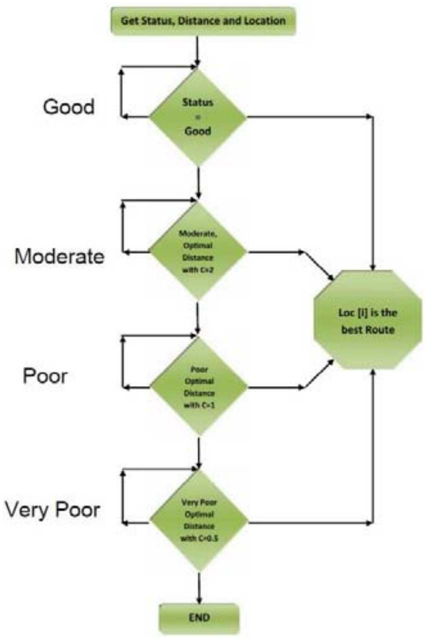

Figure 3. Flow diagram which represents the Rerouting of google map

When a passenger has to plan a travel with pollution free environment he can also view the prediction status of air pollution level of the particular location at any time. The air quality index has been estimated by time series prediction analysis using neural network and support vector machine regression algorithms. In order to predict the AQI value it's necessary to estimate the activation function using multilayer perceptron which was chosen as an approximate sigmoid for learning. Here the time Index was set automatically and the time interval was it as a daily basis. Support vector machine regression algorithm is used to minimize the error tolerated by individualizing the hyperplane which maximizes the margin. To perform the mapping implicitly, the kernel function maps the data into higher dimensional space kernel function.

4. Results and Discussions

In this paper, to monitor the air pollution we have developed a model in which the quality of air is measured by placing 5 different sensors in order to estimate the Pollutants present in air. According to international standards the quality of air is measured by its air quality index value. So from these parameters the AQI values are estimated. As mentioned in the paper there are 6 different classifications for AQI category starting from good to severe air pollution. Figure 4 represents the good air quality index in which the value of AQI where is from 0 to 50. The particulate matter varies from 0 to 50, nitrogen oxide varies from 0 to 40, ozone where is from 0 to 50, carbon monoxide varies from 0 to 1.0 and Sulphur dioxide where is from 0 to 40. This is based on 24 hour average concentration.

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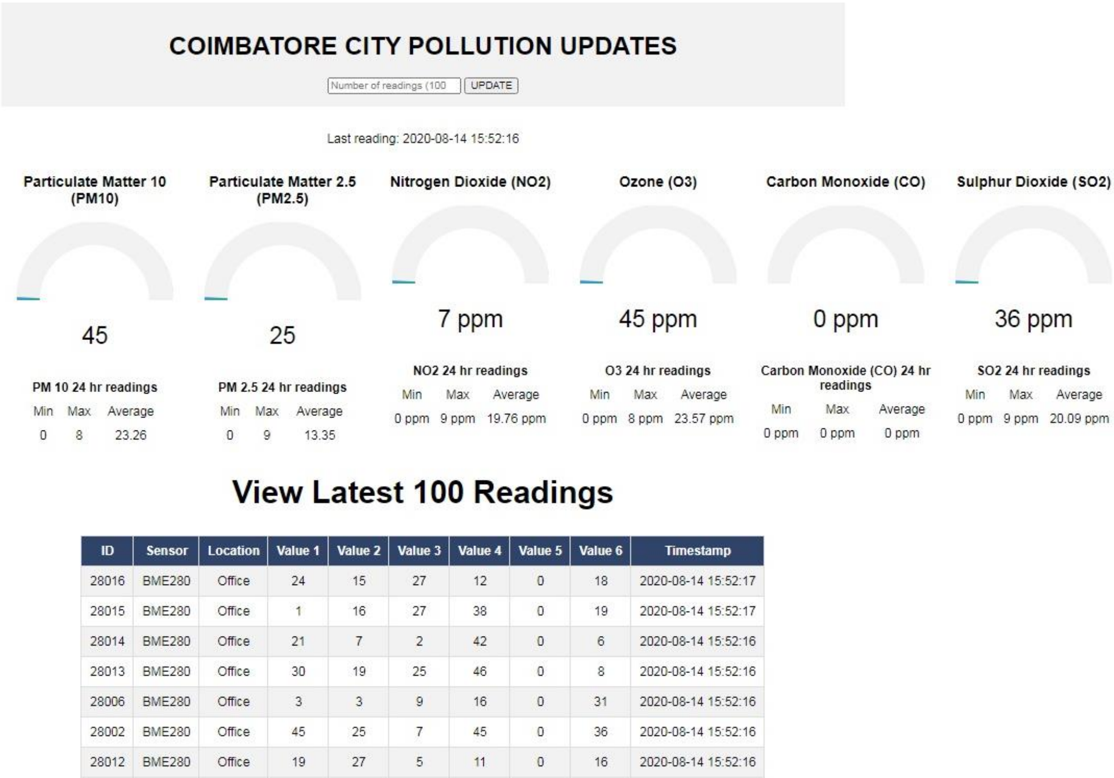
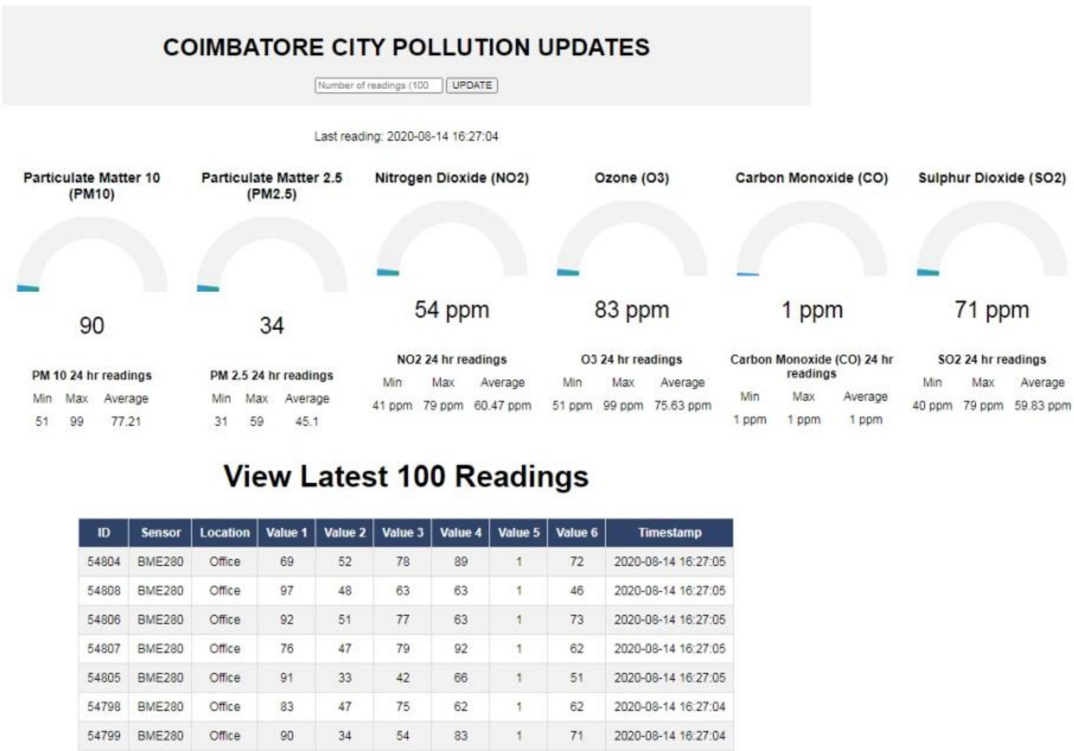


ID	Sensor	Location	Value 1	Value 2	Value 3	Value 4	Value 5	Value 6	Timestamp
28016	BME280	Office	24	15	27	12	0	18	2020-08-14 15:52:17
28015	BME280	Office	1	16	27	38	0	19	2020-08-14 15:52:17
28014	BME280	Office	21	7	2	42	0	6	2020-08-14 15:52:16
28013	BME280	Office	30	19	25	46	0	8	2020-08-14 15:52:16
28006	BME280	Office	3	3	9	16	0	31	2020-08-14 15:52:16
28002	BME280	Office	45	25	7	45	0	36	2020-08-14 15:52:16
28012	BME280	Office	19	27	5	11	0	16	2020-08-14 15:52:16

Figure 4. Pollution update for AQI Ranging from 0-50



ID	Sensor	Location	Value 1	Value 2	Value 3	Value 4	Value 5	Value 6	Timestamp
54804	BME280	Office	69	52	78	89	1	72	2020-08-14 16:27:05
54808	BME280	Office	97	48	63	63	1	46	2020-08-14 16:27:05
54806	BME280	Office	92	51	77	63	1	73	2020-08-14 16:27:05
54807	BME280	Office	76	47	79	92	1	62	2020-08-14 16:27:05
54805	BME280	Office	91	33	42	66	1	51	2020-08-14 16:27:05
54798	BME280	Office	83	47	75	62	1	62	2020-08-14 16:27:04
54799	BME280	Office	90	34	54	83	1	71	2020-08-14 16:27:04

Figure 5. Pollution update for AQI Ranging from 51- 100

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Figure 5 represents the pollution updates for Air quality index ranging from 51 to 100 and this represents the satisfactory range. The particulate matter values vary from 51 to 100, the nitrous oxide vary from 41 to 80, the ozone varies from 51 to 100, the carbon monoxide varies from 1.1 to 2.0 and the sulphur dioxide varies from 41 to 80.

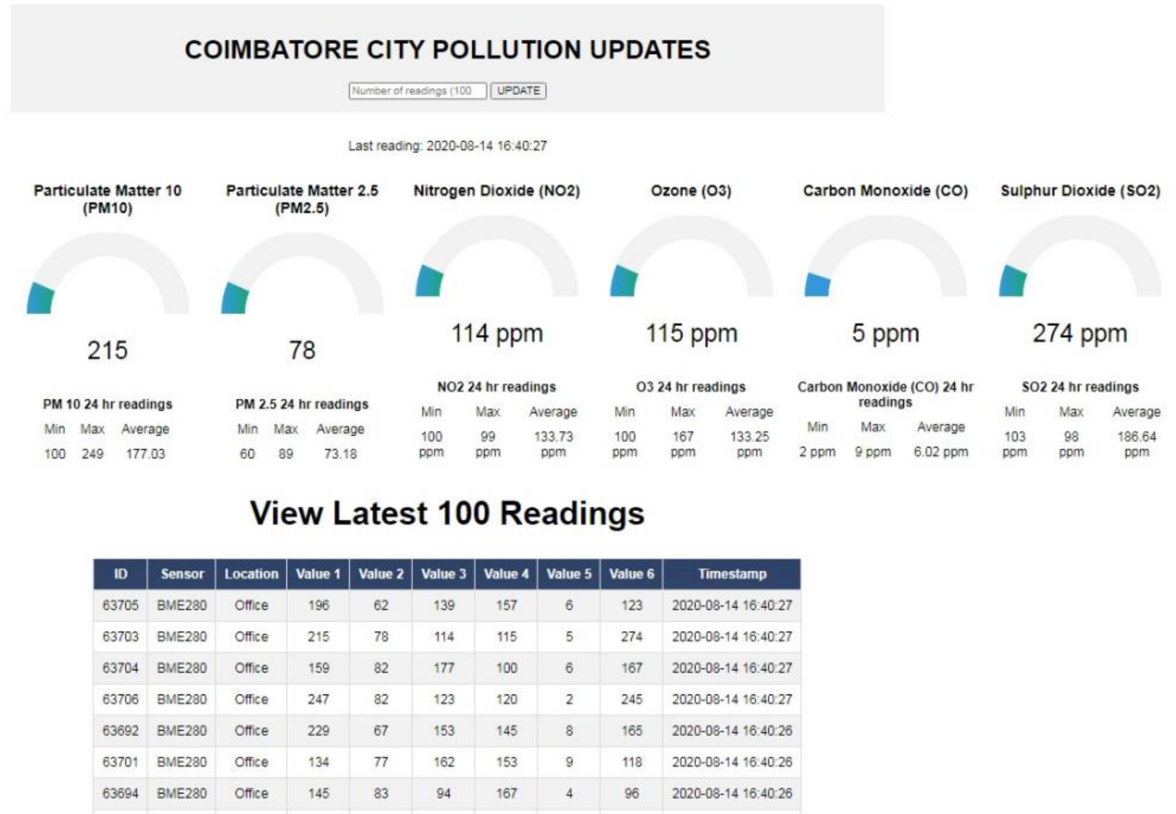
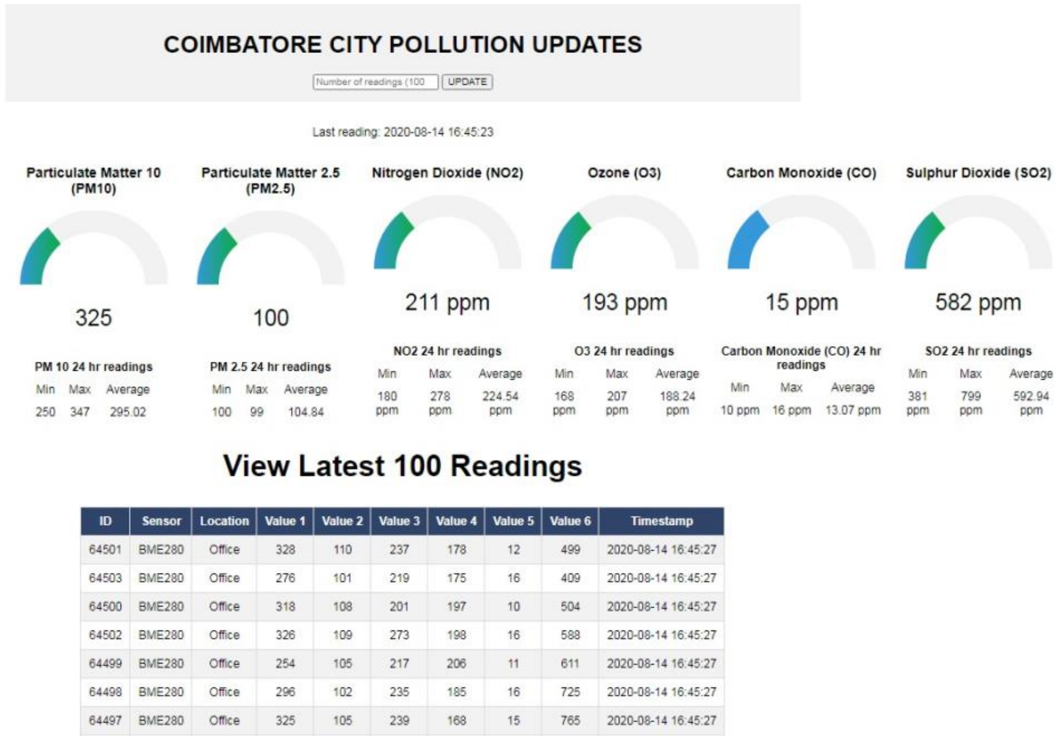


Figure 6. Pollution update for AQI Ranging from 101- 200

Figure 6 represent the pollution updates for Air quality index ranging from 101 to 200 and this represents the moderately polluted area. The particulate matter value varies from 101 to 250, the nitrous oxide varies from 81 to 180, the ozone layer is from 101 to 168, the carbon monoxide varies from 10 to 17 and Sulphur dioxide varies from 81 to 380.

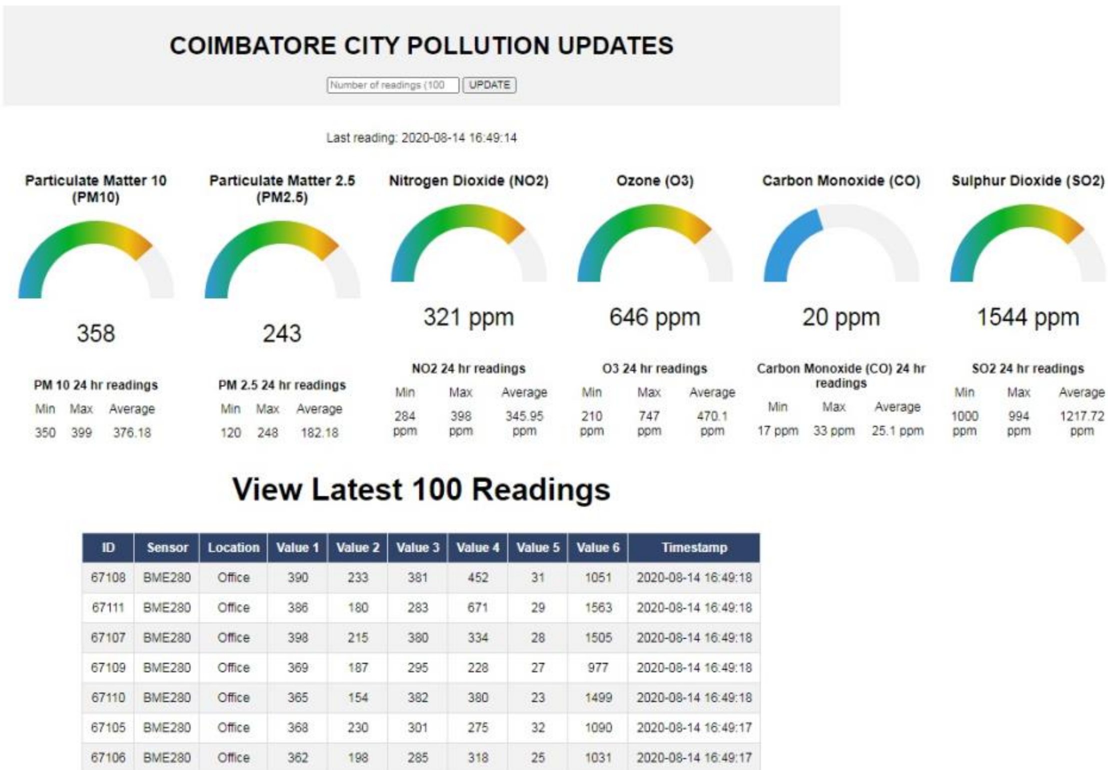
Figure 7 represents the pollution updates for Air quality index ranging from 201 to 300 and this represents the poor polluted area. The particulate matter value varies from 251 to 350, the nitrous oxide value varies from 181 to 280, the ozone varies from 169 to 208, the carbon monoxide value varies from 10 to 17 and Sulphur dioxide varies from 381 to 800.

Figure 8 represents the pollution updates for Air quality index ranging from 301 to 400 and this represents the Very poor polluted area. The particulate matter value varies from 351 to 430, the nitrous oxide value varies from 281 to 400, the ozone varies from 209 to 748, the carbon monoxide value varies from 18 to 34 and Sulphur dioxide varies from 801 to 1600.



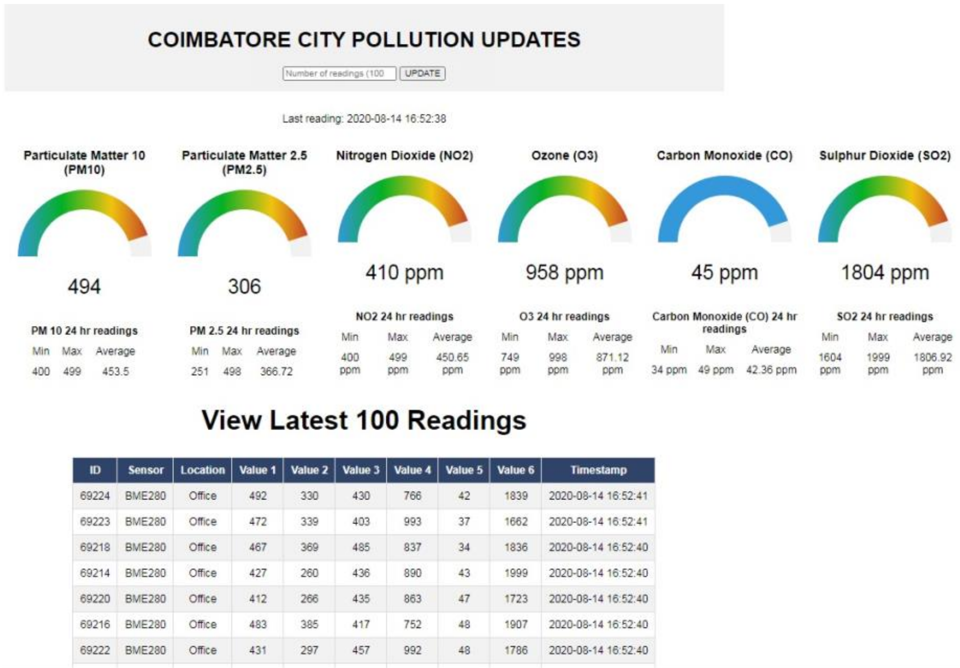
ID	Sensor	Location	Value 1	Value 2	Value 3	Value 4	Value 5	Value 6	Timestamp
64501	BME280	Office	328	110	237	178	12	499	2020-08-14 16:45:27
64503	BME280	Office	276	101	219	175	16	409	2020-08-14 16:45:27
64500	BME280	Office	318	108	201	197	10	504	2020-08-14 16:45:27
64502	BME280	Office	326	109	273	198	16	588	2020-08-14 16:45:27
64499	BME280	Office	254	105	217	206	11	611	2020-08-14 16:45:27
64498	BME280	Office	296	102	235	185	16	725	2020-08-14 16:45:27
64497	BME280	Office	325	105	239	168	15	765	2020-08-14 16:45:27

Figure 7. Pollution update for AQI Ranging from 201- 300



ID	Sensor	Location	Value 1	Value 2	Value 3	Value 4	Value 5	Value 6	Timestamp
67108	BME280	Office	390	233	381	452	31	1051	2020-08-14 16:49:18
67111	BME280	Office	386	180	283	671	29	1563	2020-08-14 16:49:18
67107	BME280	Office	398	215	380	334	28	1505	2020-08-14 16:49:18
67109	BME280	Office	369	187	295	228	27	977	2020-08-14 16:49:18
67110	BME280	Office	365	154	382	380	23	1499	2020-08-14 16:49:18
67105	BME280	Office	368	230	301	275	32	1090	2020-08-14 16:49:17
67106	BME280	Office	362	198	285	318	25	1031	2020-08-14 16:49:17

Figure 8. Pollution update for AQI Ranging from 301- 400



ID	Sensor	Location	Value 1	Value 2	Value 3	Value 4	Value 5	Value 6	Timestamp
69224	BME280	Office	492	330	430	766	42	1839	2020-08-14 16:52:41
69223	BME280	Office	472	339	403	993	37	1662	2020-08-14 16:52:41
69218	BME280	Office	467	369	485	837	34	1836	2020-08-14 16:52:40
69214	BME280	Office	427	260	436	890	43	1999	2020-08-14 16:52:40
69220	BME280	Office	412	266	435	863	47	1723	2020-08-14 16:52:40
69216	BME280	Office	483	385	417	752	48	1907	2020-08-14 16:52:40
69222	BME280	Office	431	297	457	992	48	1786	2020-08-14 16:52:40

Figure 9. Pollution update for AQI Ranging from 301- 400

Figure 9 represents the pollution updates for Air quality index ranging from 401 to 500 and this represents the severe polluted area. The particulate matter value varies above 430, the nitrous oxide value varies above 400, the ozone varies above 748, the carbon monoxide value varies above 34 and Sulphur dioxide varies above 1600.

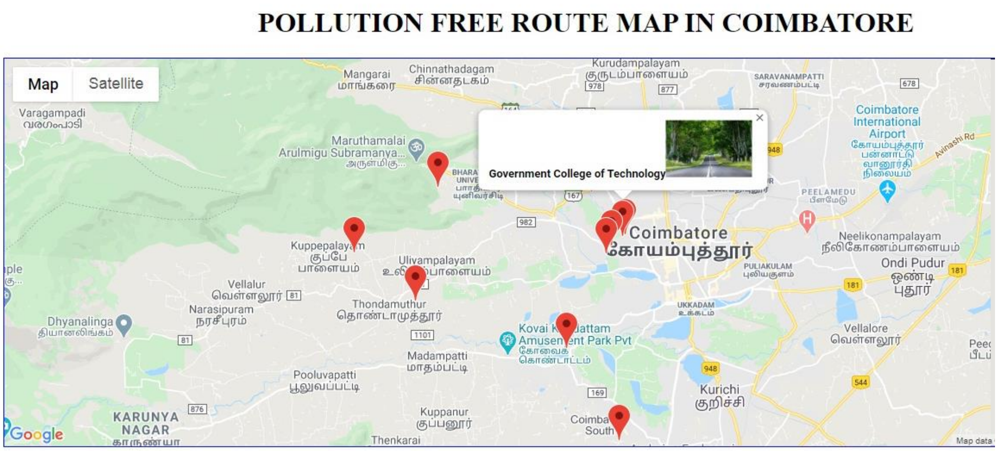


Figure 10. Screenshot of the Map with data points in map view

Figure 10 represents the updation of air quality index value in which the sensors are placed. The Air quality index value updated for every hour so that the passenger who travels from one place to another place can be is rerouted via the optimal distance calculated as well as without pollution. The prediction also can be done by using support vector machine regression algorithm which is used to predict the pollutions status so that a person can plan his trip prior to a polluted area.

5. Conclusion

This work deliberates the implementation of cloud based IoT system for air quality monitoring in which the sensors are used to calculate CO, PM2.5 and PM10, O3, SO2 and NOx pollution level with environmental condition like temperature and humidity. The estimated sensor values are transmitted into the network by using NB IoT devices and this information is processed at cloud environment. The AQI value is estimated and using these values the pollution conditions are updated in maps. By using these updated values a passenger can select a route without pollution. The passenger can also plan a travel in prior by predicting the AQI value using machine learning algorithm.

References

[1] S. Duangsuwan, A. Takarn, and P. Jamjareegulgarn, "A Development on Air Pollution Detection Sensors based on NB-IoT Network for Smart Cities," *Isc. 2018 - 18th Int. Symp. Commun. Inf. Technol.*, no. Iscit, pp. 313–317, 2018, doi: 10.1109/ISCIT.2018.8587978.
[2] M. L. Moses and B. Kaarthick, "Multiobjective cooperative swarm intelligence algorithm for uplink resource allocation in LTE-A networks," *Trans. Emerg. Telecommun. Technol.*, vol. 30, no. 12, 2019, doi: 10.1002/ett.3748.
[3] S. Maurya, S. Sharma, and P. Yadav, "Internet of Things based Air Pollution Penetrating System using GSM and GPRS," *2018 Int. Conf. Adv. Comput. Telecommun. ICACAT 2018*, vol. 1, 2018, doi: 10.1109/ICACAT.2018.8933788.
[4] R. D. Dua, D. M. Madaan, P. M. Mukherjee, and B. L. Lall, "Real time attention based bidirectional long short-term memory networks for air pollution forecasting," *Proc. - 5th IEEE Int. Conf. Big Data Serv. Appl. BigDataService 2019, Work. Big Data Water Resour. Environ. Hydraul. Eng. Work. Medical, Heal. Using Big Data Technol.*, pp. 151–158, 2019, doi: 10.1109/BigDataService.2019.00027.
[5] M. Korunoski, B. R. Stojkoska, and K. Trivodaliev, "Internet of Things Solution for Intelligent Air Pollution Prediction and Visualization," *EUROCON 2019 - 18th Int. Conf. Smart Technol.*, pp. 1–6, 2019, doi: 10.1109/EUROCON.2019.8861609.
[6] B. Maity, Y. Polapragada, A. Ghosh, S. Bhattacharjee, and S. Nandi, "Identifying Outdoor Context by Correlating Air and Noise Pollution Sensor Log," *2020 Int. Conf. Commun. Syst. NETworkS, COMSNETS 2020*, pp. 891–893, 2020, doi: 10.1109/COMSNETS48256.2020.9027364.
[7] P. Zhao and K. Zettsu, "Convolution Recurrent Neural Networks Based Dynamic Transboundary Air Pollution Predictiona," *2019 4th IEEE Int. Conf. Big Data Anal. ICBDA 2019*, pp. 410–413, 2019, doi: 10.1109/ICBDA.2019.8712835.
[8] R. K. Kodali, S. Pathuri, and S. C. Rajnarayanan, "Smart indoor air pollution monitoring station," *2020 Int. Conf. Comput. Commun. Informatics, ICCCI 2020*, pp. 20–24, 2020, doi: 10.1109/ICCCI48352.2020.9104080.
[9] K. B. Shaban, A. Kadri, and E. Rezk, "Urban air pollution monitoring system with forecasting models," *IEEE Sens. J.*, vol. 16, no. 8, pp. 2598–2606, 2016, doi: 10.1109/JSEN.2016.2514378.
[10] M. L. Moses and B. Kaarthick, "Qos-aware memetic-based optimal cross-layer resource allocation in mixed lte networks," *Int. J. Recent Technol. Eng.*, vol. 8, no. 3, pp. 5930–5938, 2019, doi: 10.35940/ijrte.C6150.098319.
[11] V. S. Esther Pushpam, N. S. Kavitha, and A. G. Karthik, "IoT Enabled Machine Learning for Vehicular Air Pollution Monitoring," *2019 Int. Conf. Comput. Commun. Informatics, ICCCI 2019*, pp. 1–7, 2019, doi: 10.1109/ICCCI.2019.8822001.
[12] N. Vijaranakul, S. Jaiyen, P. Srestasathiern, and S. Lawawirojwong, "Air Quality Assessment Based on Landsat 8 Images Using Supervised Machine Learning Techniques," no. March 2019, pp. 96–100, 2020.
[13] A. Barve, "Air Quality Index forecasting using parallel Dense Neural Network and LSTM cell," pp. 8–11, 2020.