(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) **World Intellectual Property Organization**
International Bureau

(43) **International Publication Date**
**23 March 2023 (23.03.2023)**

(10) **International Publication Number**
**WO 2023/042222 A1**

(51) **International Patent Classification:**
*H04W 4/38* (2018.01) *G01N 33/00* (2006.01)

(21) **International Application Number:** PCT/IN2022/050826

(22) **International Filing Date:** 15 September 2022 (15.09.2022)

(25) **Filing Language:** English

(26) **Publication Language:** English

(30) **Priority Data:**
202141042001 16 September 2021 (16.09.2021) IN

(71) **Applicants: INDIAN INSTITUTE OF TECHNOLOGY MADRAS (IIT MADRAS)** [IN/IN]; The Dean, Industrial Consultancy & Sponsored Research [IC&SR], Indian Institute of Technology Madras, IIT Post, Chennai, Tamil Nadu 600036 (IN). **INDIAN INSTITUTE OF TECHNOLOGY DELHI (IIT DELHI)** [IN/IN]; Hauz Khas, New Delhi 110016 (IN).

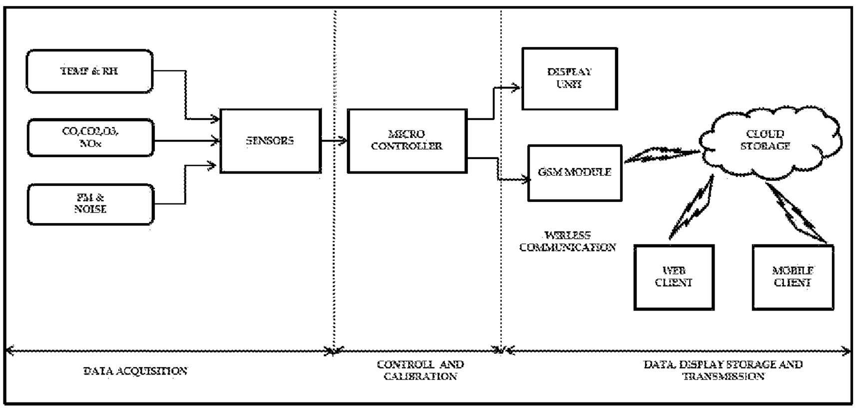
(72) **Inventors: S. M, Shiva Nagendra**; Department of Civil Engineering, EWRE Division, Indian Institute of Technology Madras (IIT Madras), IIT Post, Chennai, Tamil Nadu, 600036 (IN). **JALIHAL, Devendra**; Department of Electrical Engineering, Indian Institute of Technology Madras (IIT Madras), IIT Post, Chennai, Tamil Nadu, 600036 (IN). **V, Kamakoti**; Department of Computer Science and Engineering, Indian Institute of Technology Madras (IIT Madras), IIT Post, Chennai, Tamil Nadu, 600036 (IN). **KHARE, Mukesh**; Department of Civil Engineering, Indian Institute of Technology Delhi (IIT Delhi), Hauz Khas, New Delhi 110016 (IN). **M, Vijayakumar**; Department of Civil Engineering, EWRE Division, Indian Institute of Technology Madras (IIT Madras), IIT Post, Chennai, Tamil Nadu, 600036 (IN). **NARAYANA, Mannan Veera**; Department of Electrical Engineering, Indian Institute of Technology Madras (IIT Madras), IIT Post, Chennai, Tamil Nadu, 600036 (IN). **J, Aswin Giri**; Department of Civil Engineering, EWRE Division, Indian Institute of Technology Madras (IIT Madras), IIT Post, Chennai, Tamil Nadu, 600036 (IN).

(74) **Agent: PUTHRAN, Elizabeth**; PUTHRAN & ASSOCIATES, B- 3, Kesavan Orchid, 5/7, North Mada Street, Sri Nagar Colony, Saidapet, Chennai, Tamil Nadu, 600 015 (IN).

(81) **Designated States** *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CV, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IQ, IR, IS, IT, JM, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU,

(54) **Title:** SENSOR NETWORK FOR AMBIENT AIR QUALITY MONITORING

**Fig 1**




(57) **Abstract:** This present invention has a design of power efficient low cost sensor based real time air quality sensor network. The said sensor module has gaseous pollutant sensors like NOx, SOx, O3, CO, and optical image based PM2.5 and PM10 sensors for particulate matter, integrated with microcontroller based embedded electronics technology with specially designed air sampling medium to ensure the measurement accuracy and GSM/Wi-Fi based wireless platform in order to collect the air quality data through the wireless networking of sensor nodes. The pollution monitoring data can be uploaded to the secure server for data collection and forecasting of air pollution data and information. The real time monitoring of the present application will help in calculating air quality index to issue health advisories as well as for formulation of control measures to ensure compliance.

WO 2023/042222 A1

[Continued on next page]

LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) **Designated States** *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

**Declarations under Rule 4.17:**
— *as to the identity of the inventor (Rule 4.17(i))*
— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*
— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*
— *of inventorship (Rule 4.17(iv))*

**Published:**
— *with international search report (Art. 21(3))*
— *in black and white; the international application as filed contained color or greyscale and is available for download from PATENTSCOPE*

# SENSOR NETWORK FOR AMBIENT AIR QUALITY MONITORING

## FIELD OF THE INVENTION:

[0001] The present invention relates sensor based wireless sensor network (WSN) for real time ambient air quality monitoring. More specifically the present invention relates to the wireless ambient air quality sensor network having higher data accuracy and data validation, improved with adaptive field calibration technique.

## BACKGROUND:

[0002] The present national air quality monitoring network is limited in scope as the recorded values are indicative and there is immense time lag in reporting the data. So real time action is not possible. Also, involvement of various monitoring agencies, personnel and equipment in sampling, chemical analyses and data reporting brings uncertainty and biases. Even with the existing system, the number of non-attainment cities is very high. As many as 131 cities are exceeding the permissible limit for PM10, and 18 cities are exceeding the permissible limit for NO2. Therefore, it is the action that matters even as we upgrade our monitoring systems.

[0003] The ambient air quality in India is monitored collectively by CPCB, state pollution control boards (SPCBs), pollution control committees (PCCs), and National Environmental Engineering Research Institute (NEERI) in 215 cities and towns. A total of 523 manual monitoring stations are being operated across states. Some states have set up additional monitoring stations in cities. However, there is a shortfall in operation as about 1,000 stations with additional continuous ambient air quality monitoring (CAAQM) stations that report data real time, are required. Real time monitoring results will help in calculating air quality index to issue health advisories as well as for formulation of action plan to meet standards.

[0004] Traditional real-time air quality monitoring instruments are expensive to install and maintain; therefore, such existing air quality monitoring networks are sparsely deployed and lack the measurement density to develop high-resolution spatiotemporal air pollutant maps.

[0005] Tsujita et al. (2004) evaluated the performance of air quality sensors with the reference monitoring station.

[0006] Moltchanov et al. (2015)– studied ambient measurements of gaseous air pollutants by a network consisting of six wireless multi-sensor miniature nodes deployed in three urban sites spaced 150 m apart.

[0007] The results demonstrate the network's capability to capture spatio-temporal concentration variations at an exceptional fine resolution but highlight the need for a frequent in-situ calibration to maintain the consistency of sensors. Lin et al. (2015) evaluated and calibrated Aeroqual series 500 . portable gas sensors accurate measurement of ambient O3 and NO2.

[0008] Spinelle et al (2015) evaluated the performance of several field calibration methods for low cost sensors, including linear/multi linear regression and supervised learning techniques . Moltchanov et al. (2015) described the field calibration in following steps:

1. Identification of reference station
2. Location of sensor nodes
3. Comparison of sensor concentration data with reference station concentration data under variable ambient temperature and humidity.

[0009] The prior art CN108414682A relates to an air quality monitoring technology and especially relates to a method for quickly calibrating air quality monitoring data based on a wireless sensor network. The method comprises the following steps: a standard high-precision air quality collection device and collection of data from every sensor node; the calibration equation parameter of every sensor node is obtained using a big data analysis platform, and is stored; a real-time online calibration subsystem receives the air quality monitoring data uploaded by the sensor nodes and establishes an air quality data feature vector set; and the big data analysis platform calculates the real-time air quality data according to the air quality data feature vector set and the stored calibration equation parameter. The method maximally reduces the systematic error of the multi-dimensional air quality data collected by the sensor nodes to quickly provide accurate air quality data, and can be applied to systems for monitoring the air quality in a self-perceived environment, cared by people, in real time and predicating life and medical weather indexes.

[00010] The prior art US9291608B2 discloses a method of calibrating sensors in a distributed sensor system with a set of spatially distributed base units in communication with a central server over a data network using a reference sensor, a reference base unit, crowd-sourced calibration, sensor data collected in the same base unit, sensor cross-sensitivity, or using sensor data from known environmental conditions.

[00011] More recently, low-cost sensors have been used to collect high-resolution spatial and temporal air pollution data in real-time.

[00012] However, the field calibration of air quality sensor network, an important aspect to provide accurate and reliable data for pollution measurement is not available and not addressed till date, this forms an integral part of the present invention.

**OBJECTS OF THE INVENTION:**

[00013] The primary object of the present invention is to provide a method of real-time air quality monitoring using sensor network.

[00014] Another object of the present invention is to provide a low cost sensor based wireless sensor network (SENSurAIR) to collect high-resolution spatial and temporal air

pollution data in real-time data in real-time and pollution data forecasting on LED dashboard.

[00015] Yet another objective of the present application is development of field calibration for wireless sensor network and validation.

[00016] Yet another objective of the present application is development of secure wireless transfer protocol of air pollution monitoring and its AQI forecasting

**SUMMARY:**

[00017] To achieve the objectives, the present invention provides a method for monitoring air quality using sensors.

[00018] This invention has a design of power efficient low cost sensor based real time air quality sensor network. The developed sensor module has gaseous pollution monitoring sensors for NOx, SOx, O3, CO and optical image based PM2.5 and PM10 sensors for particulate matter, integrated with microcontroller based embedded electronics technology with specially designed air sampling medium to ensure the accuracy and GSM/Wi-Fi based wireless platform in order to achieve the wireless networking of sensor nodes to collect the air quality data.

[00019] The pollution monitoring data can be uploaded to the secure server/cloud for data collection and forecasting of air pollution data and information. In order to achieve good accuracy, reliability and sensitivity of sensor nodes ,a field calibration protocol has been developed. So the real time monitoring results will help in calculating air quality index to issue health advisories as well as for formulation of control measures to ensure compliance..

[00020] *The objective and advantages of the present invention will become more evident from the following detailed description when taken in conjunction with the accompanying drawings.*

## BRIEF DESCRIPTION OF THE DRAWINGS:

*[00021] The objective of the present invention will now be described in more detail with reference to the accompanying drawings, in which:*

[00022] FIG. 1 illustrates the block diagram of air quality monitoring sensor node;

[00023] FIG. 2 provides protocol of wireless sensor network for air quality monitoring;

[00024] FIG. 3a illustrates the calibration procedure of the present invention; and

[00025] FIG. 3b illustrates field calibration network;

## DETAILED DESCRIPTION OF THE INVENTION:

[00026] The present invention of low cost sensor based wireless sensor network contains air quality sensor with embedded controller having wireless transmission medium like LoRa Wi-Fi module and GSM/GPRS based module as illustrated in Fig 1.

[00027] The embedded sensor node contains following blocks:

[00028] Data Acquisition: - data acquisition is done by sensing the parameter involved by their respective sensors and giving the response in some other parameter. It is the first

process in the air quality monitoring unit. After data acquisition, it is used for control & calibration.

[00029] Control and Calibration: - The outputs from analog sensors are digitized using Analog-to-Digital Converter and then processed by a micro-controller. The output of digital sensors is fed directly to the microcontroller. Change in voltage levels will be transformed to corresponding concentrations. Calibration will be done at the microcontroller level in the sensor node or at the data cloud using data driven approaches.

[00030] Data transmission and storage: Most of the sensors record and transmit the data at a very high frequency, hence, producing a large amount of data in a short span of time. Thus, the data from all the sensors are transmitted to a centralized database from where it can be accessed as and when required. The data can be uploaded and downloaded, to and from the database using any one of the existing technologies like GSM or Ethernet or Wi-Fi.Display

[00031] Unit: - To display the concentration of the pollutants obtained to a larger set of audience, an LCD unit is interfaced. Also, a small LCD and the data can also be accessed using a web page or a mobile application.

[00032] Wireless Data Communication Techniques: The communication techniques serve the purpose of data collection, data sharing, remote monitoring and controlling.

[00033] The communication medium are given as following:

[00034] GSM (Global System for Mobile communications) operates using TDMA (Time Division Multiple Access) technology and is based on IEEE 802.21 protocol. It supports data transfer speeds of up to 9.6 kbps and operates in the 900MHz and 1.8GHz bands in Europe and the 1.9GHz and 850MHz bands in the US. The microcontroller is interfaced with 4G GSM Modem , a GSM module. It operates in 900MHz band on 12V, 1A DC power supply. AT

Commands are used to program the module using Serial Peripheral Interface (SPI) communication. The module uses TCP/IP stack to connect to the internet via GPRS. A unique API key indicating the IP of the server is fed to the GSM module which ensures the transmission of data to the appropriate database.

[00035] Wi-Fi/LoRa Wi-FI module

[00036] Wireless Fidelity (Wi-Fi) communicates via RF waves and can operate up to a speed of 2.8 Mbps. The information can be transferred up to a distance of 20 meters. It functions based on IEEE 802.11 protocol. The micro-controller is being interfaced with ESP8266 Wi-Fi module. It operates on 3.3V DC power supply and consumes 170mA of current. AT Commands are used to program the module using Serial Peripheral Interface (SPI) communication.

Field Calibration of Wireless Sensor Network(WSN):

[00037] Instrument calibration is one of the primary processes used to maintain instrument accuracy. Calibration is the process of configuring an instrument to provide a result for a sample within an acceptable range.

[00038] Principally, the calibration of air quality sensors are carried out using wireless signal based calibration technique: direct calibration of sensor using known concentration of pollutants: and use of collocated data from conventional fixed monitoring stations. Wireless signal based calibration techniques use telemetry to automatically transfer data from conventional monitoring stations to sensor receiver and perform single point calibration of their response. A key feature of this approach is to develop a built-in process by which a calibration signal could be received and then automatically processed. For this, it needs real time data from existing conventional monitoring stations through network design.

[00039] Direct calibration of sensor using a known concentration of gas is laboratory scale calibration. The accuracy of the method lies in the fact that, we know the purity of gas being applied to the sensor, the direct contact of gas and sensor interface is occurring, and that one might be able to maintain the residence time of the gas on the interface to overcome response (delay) features. The calibration is done under controlled environmental conditions, which may not represent actual atmospheric conditions and requires the necessary skill and experimental ability to conduct the calibration. The next option of calibration is the use of collocated data from conventional monitoring stations to normalize the response. This calibration technique can always be used to convert the raw (non-calibrated) data into a more acceptable quality.

[00040] The calibration is carried out by collocating the sensors with the conventional fixed monitoring station and comparing the sensor output to that of the monitoring station. Data driven approaches of machine learning and artificial intelligence approaches used for the complex pattern recognition in the air quality data for better calibration. Remote calibration at cloud with embedded machine learning calibration program. Various mathematical tools can be applied to check the agreement between the sensor data and the reference data.

[00041] The dynamic gas sensor network of the present invention is achieved by placing the sensors on vehicles running through the streets. The present application has presented the auto-calibration method of the dynamic gas sensor network. Results have shown that adjusting the sensor outputs to the average values of the sensors, sharing the same site, improves the measurement accuracy of sensor network.

[00042] Field calibration of O3 and NO2 sensors have also been carried out by collocating with the air quality monitoring station, which showed high intra nodal correlation of NO2 & O3, but O3 suffered considerable inter nodal variations.

[00043] The experiments have indicated that hourly-average Aeroqual O3 sensor observations are highly correlated (R2 = 0.91) and of similar magnitude to observations from

the UV-absorption reference O3 analyzer. The Aeroqual NO2 sensor observations correlated poorly with the reference chemiluminescence NO2 analyzer ($R2 = 0.02$), but the deviations between Aeroqual and reference analyzer values ([NO2]Aeroq - [NO2]ref) have been highly significantly correlated with concurrent Aeroqual O3 sensor observations [O3]Aeroq.

[00044] These field observations under temperate environmental conditions have suggested that the Aeroqual Series- 500, NO2 and O3 monitors have good potential to be useful ambient air monitoring instruments in urban environments provided that the O3 and NO2 gas sensors are calibrated against reference analyzers and deployed in parallel.

[00045] For each method, a two-week calibration has been carried out at a semi-rural site against reference measurements. The study has observed that O3 may be calibrated using simple regression techniques; while for NO2, a satisfactory agreement between sensors and reference measurements has been reached using supervised learning techniques.

[00046] Laboratory calibration is done by exposing the sensor to a known concentration of pollutant and adjusting the sensor results to the standard concentration value of the pollutant. Laboratory calibration is done under controlled conditions of temperature and humidity. These controlled conditions are generally not there in the field. Hence, the laboratory calibration has to be supported by field calibration.

[00047] Field calibration of a sensor is done by locating the sensor as close to the reference monitoring station which is known as collocation. Collocating the sensor with reference monitoring station and comparing the results of the sensor output with reference values allows adjustment of the sensor values by introducing a calibration factor to each sensor.

[00048] Protocol for Field Calibration Protocol

The calibration procedure:

a) One week (7 days) continuous monitoring will be done by collocating the three sensors of PM2.5, $NO_2$ & CO with reference to the conventional monitoring station situated at Delhi (hereby is called the reference station).

b) One of the PM2.5, $NO_2$ & CO sensors shall be kept very near to the reference station. The other two shall be kept at a distance of 1 to 2 m from the other sensor.

c) A series of performance related parameters will be evaluated such as inter node variability and correlation between sensors and reference station concentration data using statistical descriptors and linear correlation coefficient ($R^2$) and finally calibrating each sensor by reverse regression method.

*While the foregoing written description of the invention enables one of ordinary skill to make and use what is considered presently to be the best mode thereof, those of ordinary skill will understand and appreciate the existence of variations, combinations, and equivalents of the specific embodiment, method, and examples herein. The invention should therefore not be limited by the above described embodiment, method, and examples, but by all embodiments and methods within the scope of the invention as claimed.*

**WE CLAIM:**

1. A method of monitoring air quality characterized by that of:

data acquisition module comprising sensors for sensing the parameter involved by respective sensors;

control and calibration module, herein the outputs from analog sensors are digitized using Analog-to-Digital converter; herein the output of digital sensors is fed directly to the microcontroller;

microcontroller converts the change in voltage levels to appropriate concentration levels in parts-per-million (ppm);

data transmission and storage module wherein the sensors record and transmit the data at a very high frequency.

2. The method as claimed in claim 1, wherein the said sensors of the data acquisition module is done by sensing the parameter involved by their respective sensors and giving the response in the air quality monitoring unit.

3. The method as claimed in claim 1, wherein the said control and calibration module controls the outputs from analog sensors and then are digitized using Analog-to-Digital Converter and then processed by the said micro-controller.

4. The method as claimed in claim 1, wherein the said output of digital sensors is fed directly to the microcontroller wherein converts the change in voltage levels to appropriate concentration levels in parts-per-million (ppm).

5. The method as claimed in claim 1, wherein the said data transmission module comprising the sensors record and transmit the data at a very high frequency.

6. The method as claimed in claim 1, wherein the said data can be uploaded and downloaded, to and from the database using GSM or Ethernet or Wi-Fi Display Unit.

7. The method as claimed in claim 1 wherein communication techniques serve the function of data collection, data sharing, remote monitoring and controlling

8. The method as claimed in claim 1 wherein the data from all the sensors are transmitted to a centralized database from where it can be accessed as and when required.

9. The method as claimed in claim 1 wherein the said sensor module has gaseous pollution monitoring sensors such as but not limited to NOx, SOx, O3, CO and the like.

10. The method as claimed in claim 1 wherein the said GSM operates using TDMA which supports data transfer speeds; Wi-Fi/LoRa Wi-FI module; communicates via RF waves and can operate up to a speed of 2.8 Mbps.

Fig 1

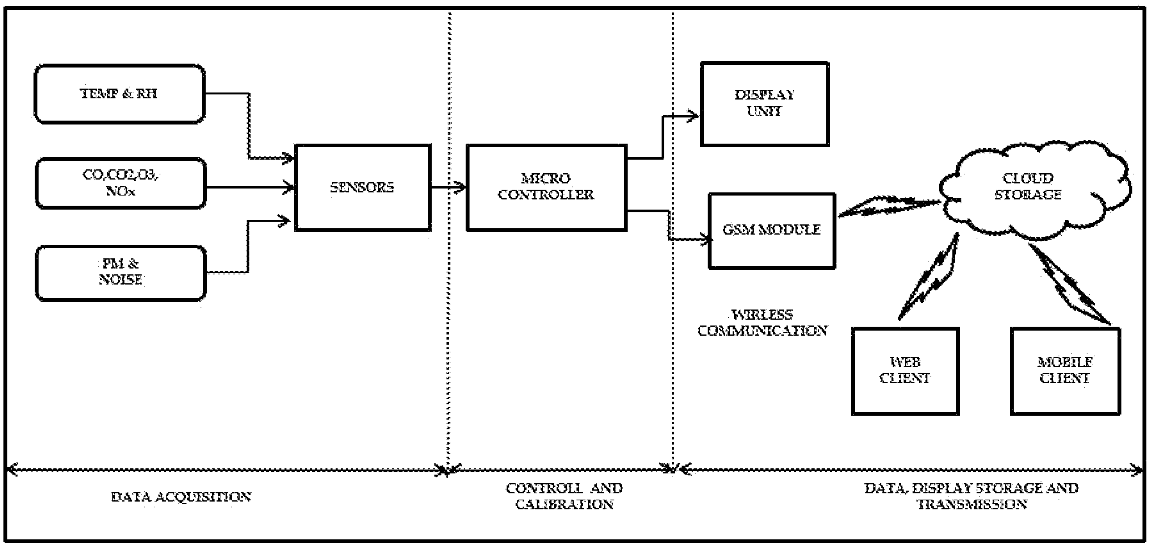

TEMP & RH
CO,CO2,O3, NOx
PM & NOISE
SENSORS
MICRO CONTROLLER
DISPLAY UNIT
GSM MODULE
CLOUD STORAGE
WIRLESS COMMUNICATION
WEB CLIENT
MOBILE CLIENT
DATA ACQUISITION
CONTROLL AND CALIBRATION
DATA, DISPLAY STORAGE AND TRANSMISSION

Fig 2

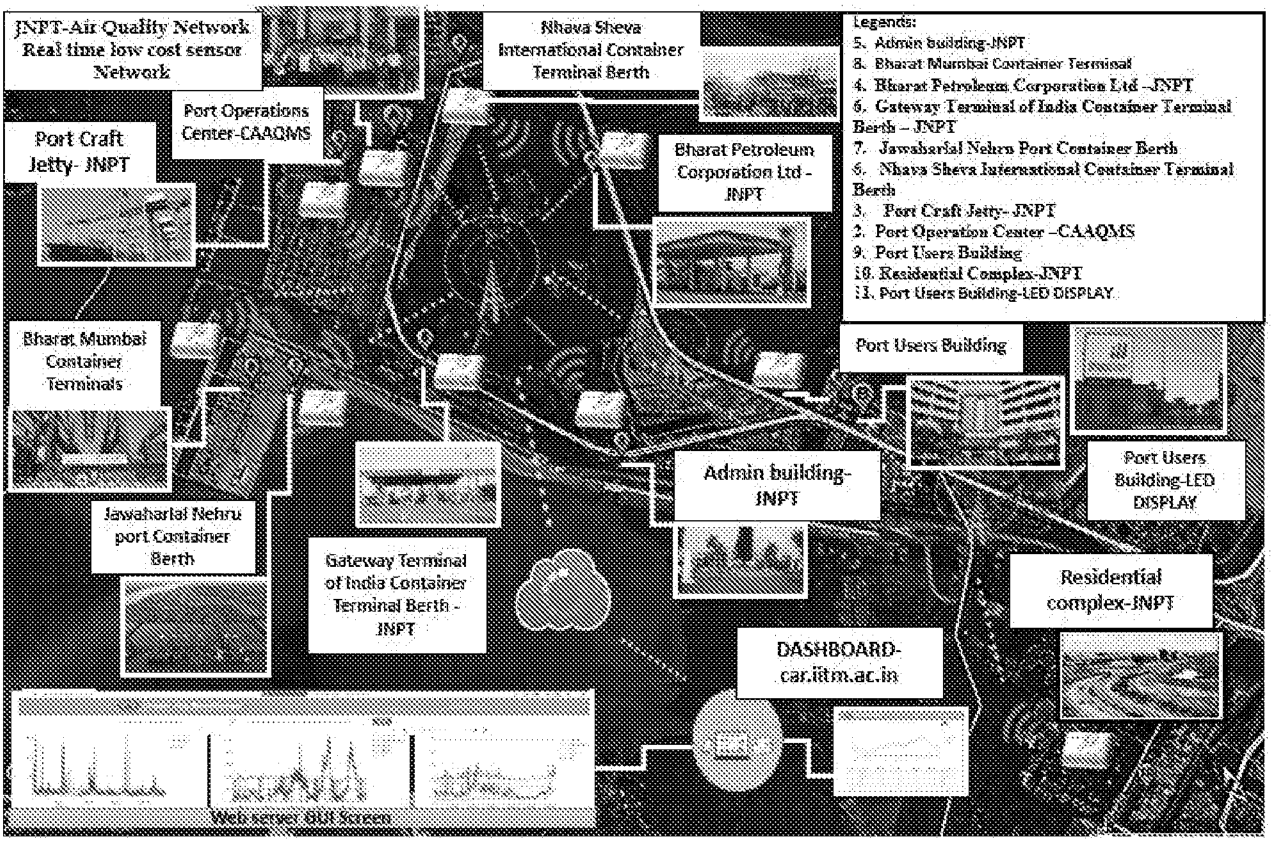

JNPT-Air Quality Network
Real time low cost sensor Network
Nhava Sheva International Container Terminal Berth
Legends:
5. Admin building-JNPT
8. Bharat Mumbai Container Terminal
4. Bharat Petroleum Corporation Ltd –JNPT
6. Gateway Terminal of India Container Terminal Berth – JNPT
7. Jawaharlal Nehru Port Container Berth
6. Nhava Sheva International Container Terminal Berth
3. Port Craft Jetty- JNPT
2. Port Operation Center –CAAQMS
9. Port Users Building
10. Residential Complex-JNPT
11. Port Users Building-LED DISPLAY
Port Operations Center-CAAQMS
Port Craft Jetty- JNPT
Bharat Petroleum Corporation Ltd - JNPT
Bharat Mumbai Container Terminals
Port Users Building
Admin building-JNPT
Port Users Building-LED DISPLAY
Jawaharlal Nehru port Container Berth
Gateway Terminal of India Container Terminal Berth - JNPT
Residential complex-JNPT
DASHBOARD-car.iitm.ac.in
Web server GUI Screen

**Fig. 3a**

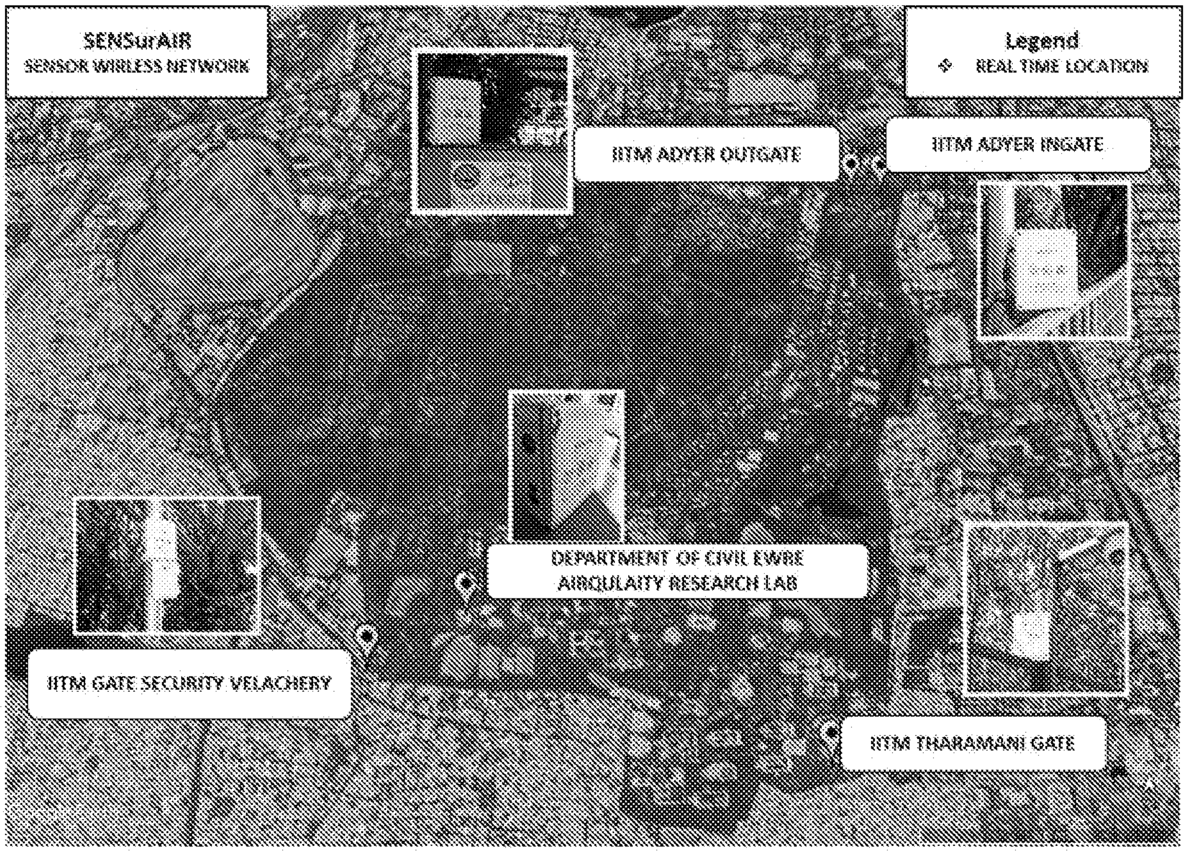
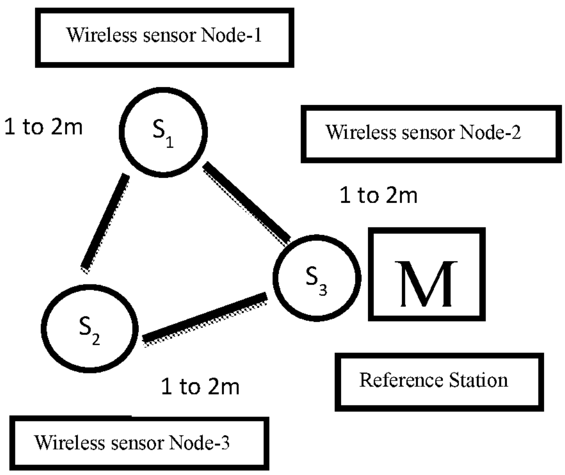

SENSurAIR
SENSOR WIRLESS NETWORK
Legend
REAL TIME LOCATION
IITM ADYER OUTGATE
IITM ADYER INGATE
DEPARTMENT OF CIVIL EWRE
AIRQULAITY RESEARCH LAB
IITM GATE SECURITY VELACHERY
IITM THARAMANI GATE

**Fig. 3b**


Wireless sensor Node-1
1 to 2m
S1
Wireless sensor Node-2
1 to 2m
S3
M
S2
1 to 2m
Reference Station
Wireless sensor Node-3

## INTERNATIONAL SEARCH REPORT

International application No.
PCT/IN2022/050826

**A. CLASSIFICATION OF SUBJECT MATTER**
H04W4/38,G01N33/00 Version=2022.01

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

H04W;G01N;

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic database consulted during the international search (name of database and, where practicable, search terms used)

Databases: PatSeer, IPO Internal Database
Keywords: monitoring air quality;Analog-to-Digital converter;

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| Y | US10563886B2 (GRAND VALLEY STATE UNIVERSITY) 18-02-2020 (18 Feb 2020) Abstract; Description; | 1-10 |
| Y | US9311805B2 (ZISHAAN FAIZ) 12-04-2016 (12 April 2016) Abstract; Description; | 1-10 |
| Y | V.S.Revathy , K.Ganesan , K.Rohini , S.Tamil Chindhu , T.Boobalan - "Air Pollution Monitoring System" IOSR Journal of Electronics and Communication Engineering (IOSR-JECE) e-ISSN: 2278-2834,p- ISSN: 2278-8735.Volume 11, Issue 2, Ver. II (Mar-Apr .2016), PP 27-40 www.iosrjournals.org Whole Document | 1-10 |

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"D" document cited by the applicant in the international application
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 21-12-2022 | 21-12-2022 |

| Name and mailing address of the ISA/ | Authorized officer |
|---|---|
| Indian Patent Office<br>Plot No.32, Sector 14,Dwarka,New Delhi-110075<br>Facsimile No. | Pankaj<br>Telephone No. +91-1125300200 |

# INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/IN2022/050826

| Citation | Pub.Date | Family | Pub.Date |
|---|---|---|---|
| US 10563886 B2 | 18-02-2020 | CA 3067992 A1 | 27-12-2018 |
| | | US 10871303 B2 | 22-12-2020 |
| | | US 2018363939 A1 | 20-12-2018 |
| | | WO 2018236571 A1 | 27-12-2018 |
| US 9311805 B2 | 12-04-2016 | US 2014031082 A1 | 30-01-2014 |