Chapter

Design and Development of Air Quality Monitoring System for Solapur City Using Smart Technologies: WSN and IoT

Tabbsum Hanif Mujawar, P. Prabhkar, Vijendra Chaudhary and Lalasaheb Deshmukh

Abstract

Owing to enhancement in technology there is inclination in miniaturization of devices which demands to build up stumpy expensive sensor, least powered and hardy devices. Accordingly, Wireless Sensor Networks (WSN) has gained significance in diverse applications: Farming, household, industries and environmental monitoring. Wireless sensor network system worn to monitor and control the air quality of an environment is developed. The air pollution monitoring system that measures temperature, humidity, SPM (Suspended Particulate Matter), NOx and CO are proposed. The conventional air quality monitoring system, prescribed by the Pollution Control Department, is tremendously pricey. Analytical measuring paraphernalia is lavish, time and power overriding, and can seldom be used for air quality exposure in real time. Endeavor has been completed to develop state of art monitoring system using commercially available standard pollutant gas sensors incorporated into a mote. An exact program made with LabVIEW is formed to constitute the measurements of sensing used in the established network. Remote monitoring of the system is made possible using IoT.

Keywords: WSN, XBee, Sensor Node, Gateway Node, IoT, Blynk Platform

1. Introduction

Fading air quality in India has moved towards malnutrition, for the past few decades. India remain one of the countries where 1.9 million untimely deaths take place due to worsening ambient air quality. The estimated financial losses caused due to air pollution in India are placed at 885 billion rupees [1, 2]. Revelation to outside air pollutants will enlarge the menace of Arrhythmia, Ischemia, Cardiac Failure and Stroke. Air quality data in Solapur has been analyzed to scrutinize its condition and to recognize its health situation.

The goal of this chapter is to tale on the development of a cost effective air quality monitoring system using wireless sensor network (WSN) and IoT, deployed in polluted areas of Solapur. The air quality in Solapur had been a tight rope walk for its citizens over the past decades [3]. Growth of Solapur had lead to rise in number of vehicles on the roads, creating supplementary pollution predicament with smoke emanation and other pollutants. Apart from the increase in vehicles, other reasons for escalating vehicular contamination are the varieties of engines used, crowded traffic, pitiable road conditions and dry climatic conditions. Solapur Municipal Corporation in alliance with Central Pollution Control Board and State Pollution Control Board has installed air quality monitoring system as an attempt of Swacch Bharat Abhiyan Project.

As data logger and hardware mechanism are not used, the present system is more superficial and user friendly. It was resolved to bail out air pollution monitoring in high traffic zones of Solapur city where pollutants exceeded the ambient air quality values as proposed by Central Pollution Control Board (CPCB). The system uses Wireless Sensor Network and IoT technology for air quality monitoring. Hitherto, the predictable monitoring system is massive, luxurious and power consuming. Therefore, incompatibility associated using wired monitoring system is replaced with a new wireless air monitoring system which is cost-effective and competent with stumpy power spending [4]. Wireless sensor networks (WSNs) are paying attention in the industry also in academia because of their significant relevance and associated security challenges. The utility of this network is to collect the data from the environment and fling it to the sink node. The present system consists of the five sensor nodes and one sink node. The chic sensor nodes are least-power gadgets outfitted with one or more sensors, microcontroller, a power supply and radio. An array of different sensors can be allied to the mote to determine environment parameters. With the establishment of 'Solapur' as smart city it becomes pertinent to employ the WSN for monitoring AAQ protocols. The smart city projects in Solapur is obligatory to put up a superior air quality monitoring system in terms of rate, power competence, ability by using contemptible handy ambient sensors. The use of IoT (Internet of Things) provides the remote monitoring of our system [5]. Internet of Things has a backbone of diverse technologies- Wireless Sensor Networks, Embedded Systems, Security Protocols and Architectures,

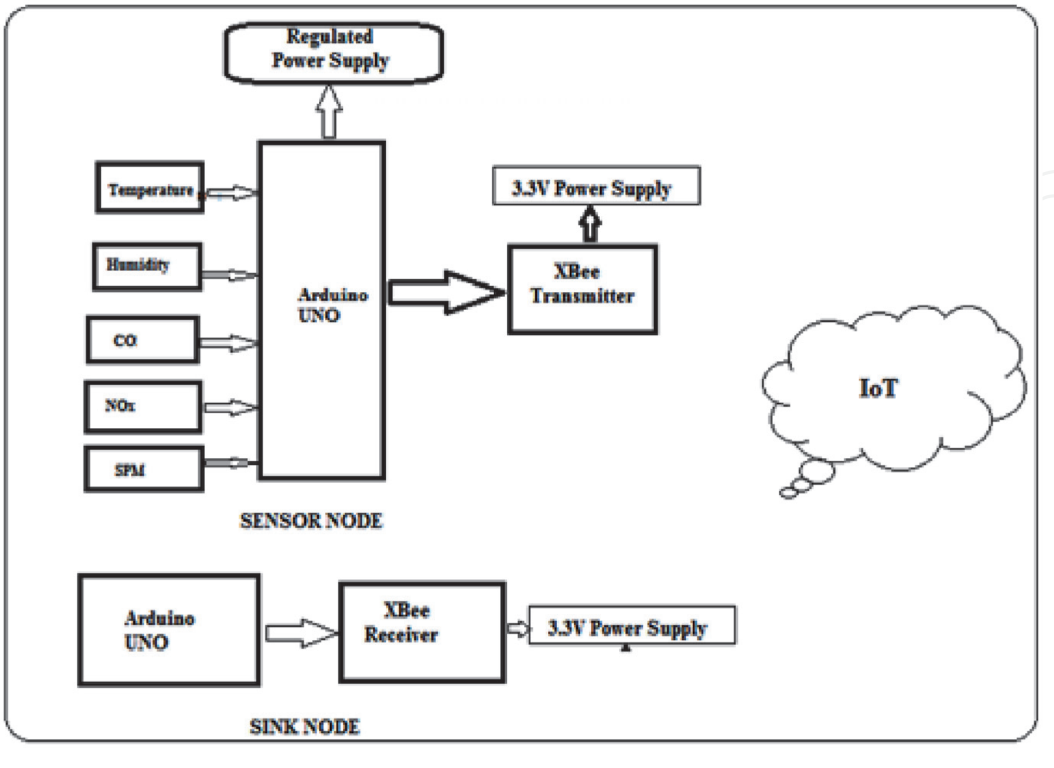

Figure 1.
Block diagram of a proposed system.

network services, Internet and Search Engines and Cloud Computing. The internet of things (IoT) is a system of unified computing gadgets, automatic and digital tackle, items, group that are provided with unique identifiers and the capability to convey data in excess of a network with no requiring user-to-user or user-to-computer dealings. Devices that work on IoT, distribute the sensor information; they amass by linking to an IoT gateway where data is sent to the cloud to be analyzed. The block diagram, **Figure 1** represents the proposed system. The use of open source IoT web server platform, to ensure an enduring storage as well as real time monitoring of air quality monitoring data makes the system more superior than the traditional data logger system. Use of flawless incorporation of smart mobile standards, WSN, and several other sensing technologies makes this system more scalable and smart. Uses of XBee wireless protocol make the system least power consumable.

2. Wireless sensor network setup for air quality monitoring system

A wireless sensor network is compacted in behavior. Generally, it provides thousands of irrelevant devices, called as sensor nodes and are incorporated to gather the data from assorted assets. The sink node collects the data from sensor node and provides necessary action on it.

2.1 Sensor node (mote)

The motes are constructed with four components (**Figure 1**), 1. Processing part made up of controller (Arduino UNO) 2. Wireless element for presuming wireless communication amid nodes (XBee) 3. Sensor to convert environment data into electrical quantity and 4. Batteries to offer power supply to the network [6]. Every constituent plays an important task in the operation of motes. Radio subsystem uses various techniques such as Bluetooth, XBee and UWB that operates at ISM band frequency of 2.4 GHz for wireless transmission. Microprocessor or microcontroller subsystem is used to offer logical decision regarding controlling of air quality monitoring system. To save energy, controller works in off, sleep, idle and active modes depending on the condition of the sensor nodes.

An array of sensors at the motes is as follows:

2.1.1 CO sensor (MQ-7)

MQ-7 Carbon monoxide sensor can sense CO gas and sends both digital and analog signals to Arduino. According to its datasheet, the MQ-7 sensor detects 20 to 2000 ppm of CO in air [7]. Its standard circuit represented in **Figure 2**. The interfacing of sensor to the arduino uno is shown in **Figure 3**.

The sensor has to be calibrated at 200 ppm of CO with R_L at 10KΩ. The load resistance R_L vary from 5KΩ to 47 KΩ. Its operating temperature range is from 20^{oc} to 50^{oc}. The surface resistance R_s varies from 2KΩ to 20KΩ. R_s can be calculated by the following formula.

$$\frac{Rs}{Rl} = (Vc - VRl)/VRl$$

From the datasheets, calibration of sensor in terms of ppm is done as follows.

$$\text{Concentration of gas(ppm)} = 3.027 * e^{\left(\left(\frac{3}{2.85}\right) * V - RL\right)}$$

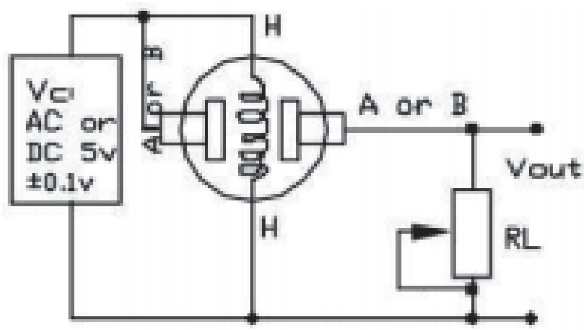

Figure 2.
Standard circuit.

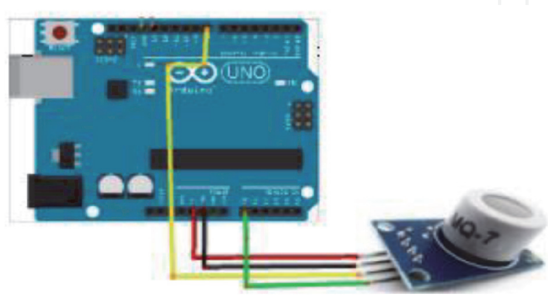

Figure 3.
Arduino interfacing of sensor.

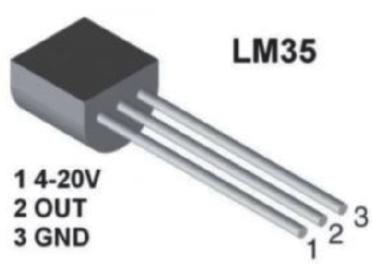

Figure 4.
Lm-35.

2.1.2 Temperature sensor (LM-35)

LM-35 is an analog temperature sensor. It is connected to A1 of arduino UNO microcontroller at sensor node. It is shown in **Figure 4**.

Vitally, LM-35 is pre-calibrated in degree celsius to be used for temperature sensor IC. It is linear in characteristics. It does not require any external calibration and gives +10-mV/°C scale facet [8]. Accordingly, the arduino encoding is carried out and its outcomes are displayed on arduino serial monitor window. The characteristic curve and arduino interfacing of LM-35 is displayed in **Figures 5** and **6**, respectively.

2.1.3 MQ-135(NO_x and SPM sensor)

The calibrated MQ-135 air quality sensor is used for detecting an extensive series of parameters, including NH_3, NOx, alcohol, benzene, SPM and CO_2. But, it shows high sensitivity for NOx and SPM [9]. Its characteristics curve is shown in **Figures 7** and **8**.

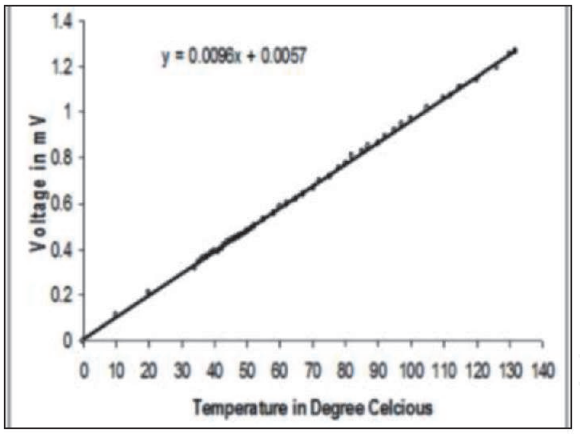

Figure 5.
LM-35 characteristics curve.

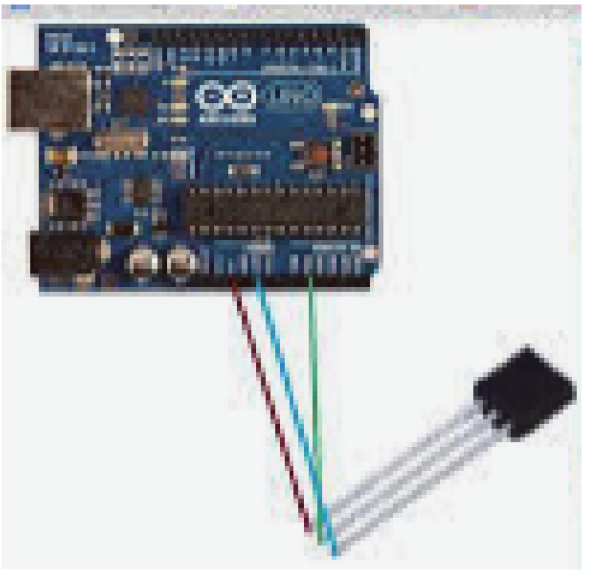

Figure 6.
Arduino interfacing.

2.1.4 Atmega 328 (controlling unit)

The Atmega 328 is an entrenched board having inbuilt USB proficiency. The minuscule and user approachable temperament makes it finer than other sophisticated microcontrollers. These microcontrollers encompass additional inbuilt amenities like +5 V, analog and digital pins. It does not comprise on board power jack. Owing to the auto switching potential of the microcontroller, no exterior power jumper is necessary [10]. It posses assorted on board pins and have advanced features as follows:

i. An automatic reset

ii. On chip broadcast and reception LED's

iii. Automatic switching to input power.

iv. Inbuilt USB flair for serial communication

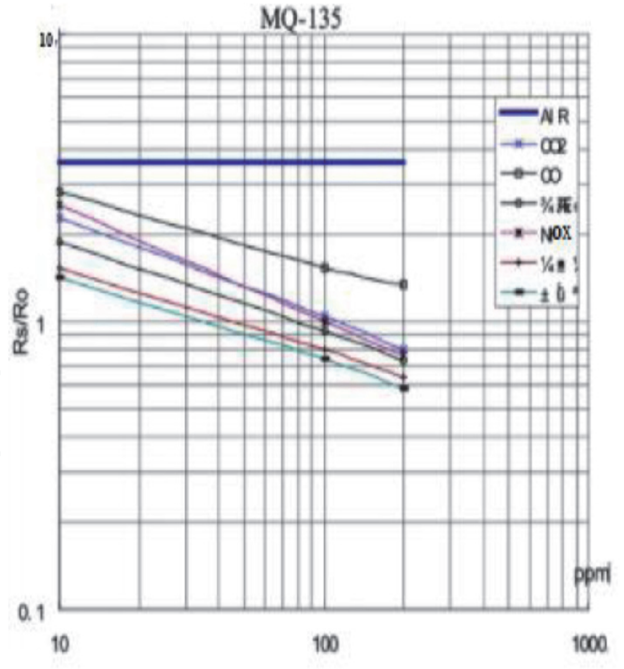

Figure 7.
Characteristics curve of MQ-135.

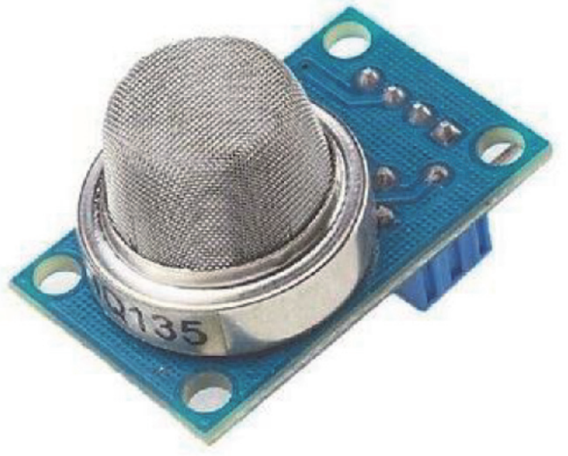

Figure 8.
MQ-135.

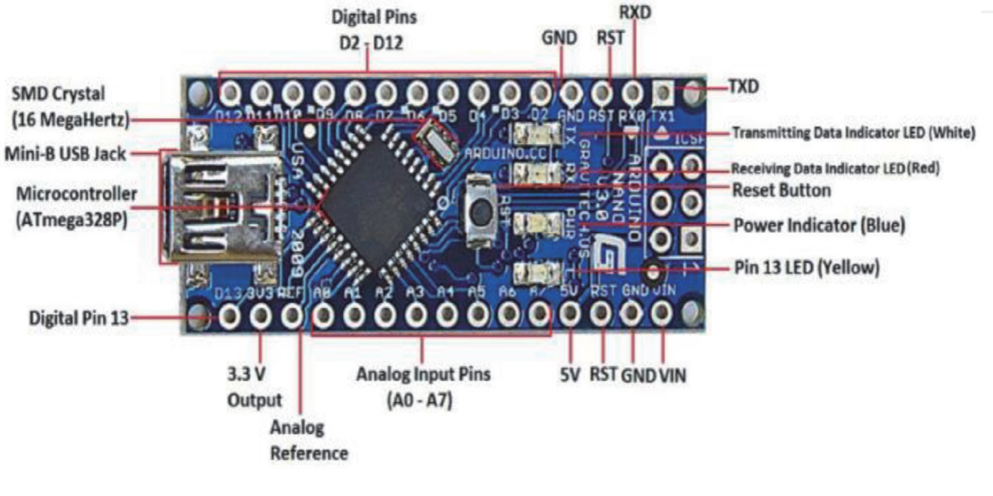

Figure 9.
Arduino nano pin configurations.

DOI: http://dx.doi.org/10.5772/intechopen.98755

Consequently, the WSN nodes are premeditated using arduino nano-microcontroller. An actual pin specification of arduino nano is depicted in **Figure 9**.

2.1.5 XBee protocol

XBee is perched to suit the comprehensive control/sensor network standard. Usually, this module consists of a 16-bit microcontroller amid all parts as some 16 – bit microcontroller might have (ADC, timer, watchdog, sleep timer, UART, general-purpose I/O port … .etc.). The schematic representation of XBee is shown in **Figure 10**.

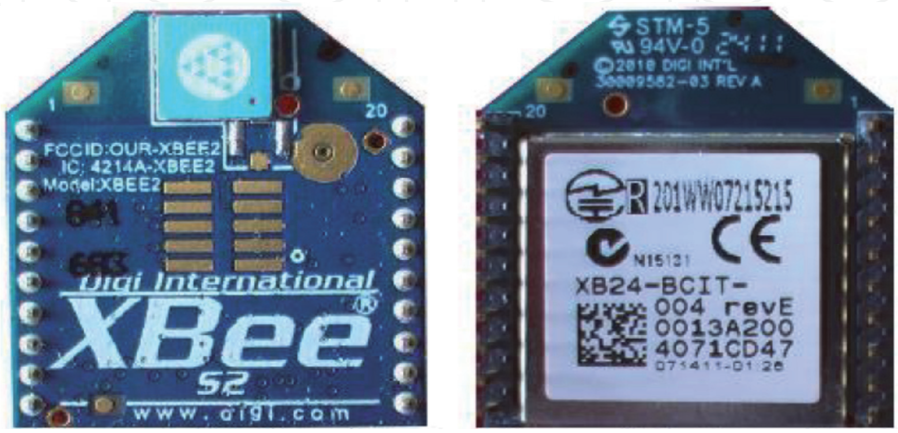

Figure 10.
XBee.

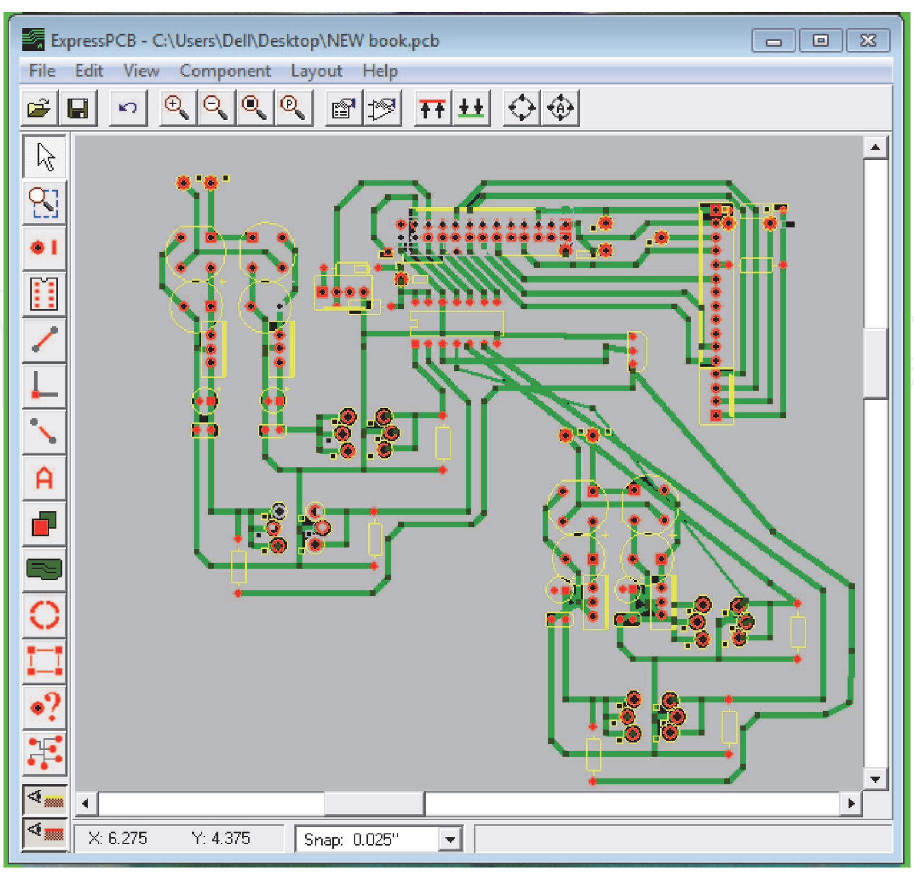

Figure 11.
PCB layout of the sensor node.

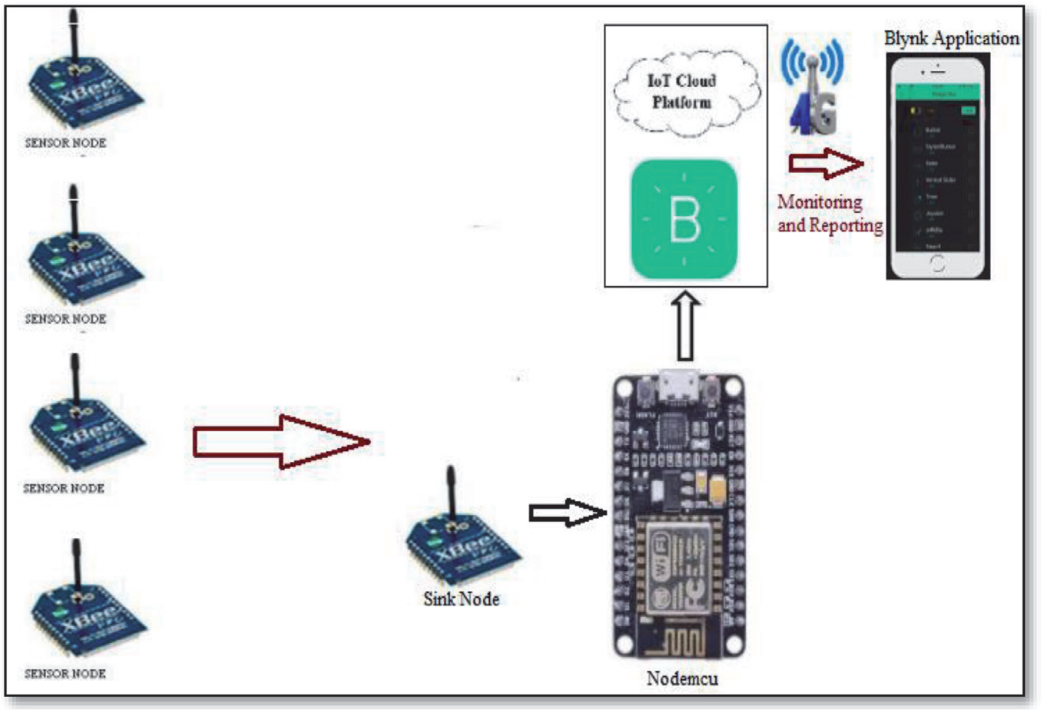

Figure 12.
Sink node setup of the present system.

Owing to the compensation of XBee technology like squat rate and stumpy power working modes and its topologies, this diminutive range communication technology is most excellent, suitable for numerous applications compared to other communications technologies such as Bluetooth, WI-FI, [11] etc. The PCB layout of sensor node drawn is shown in **Figure 11**.

The sink node of air pollution monitoring system is shown in **Figure 12**.

3. IoT (internet of things)

The IoT based air contamination monitoring system can be created via sensors and microcontrollers existing in the marketplace. The sink nodes are programmed to collect the data from the mote and transmit it to the cloud. An algorithm is proposed to examine the data and hurl it to the smart phone app. Smartphone app will be developed for user to access the air quality information in real-time [12, 13]. The IoT monitoring is scamper on the communication protocol maneuver. Internet of Things is now verdict reflective exploit in each and every area, plays an important role in this monitoring system too. This system monitors the effluence source from anywhere via PC or mobile. The system shows the air pollution in ppm on webpage, accordingly continuous monitoring can be done. IoT makes almost all "smart" which ameliorate aspects of our existence with the supremacy of data collection and networks. The thing in IoT can compared to be similar to a human being amid a diabetes supervise embed, an animal with tracking plans, etc. The basic block of IoT is depicted in **Figure 13**.

3.1 Blynk platform

Blynk is a podium with iOS and Android apps to control Arduino over the internet and is shown in **Figure 14**. It is a digital control panel where we can construct a advantage for our system by just dragging and dropping gadget. Blynk

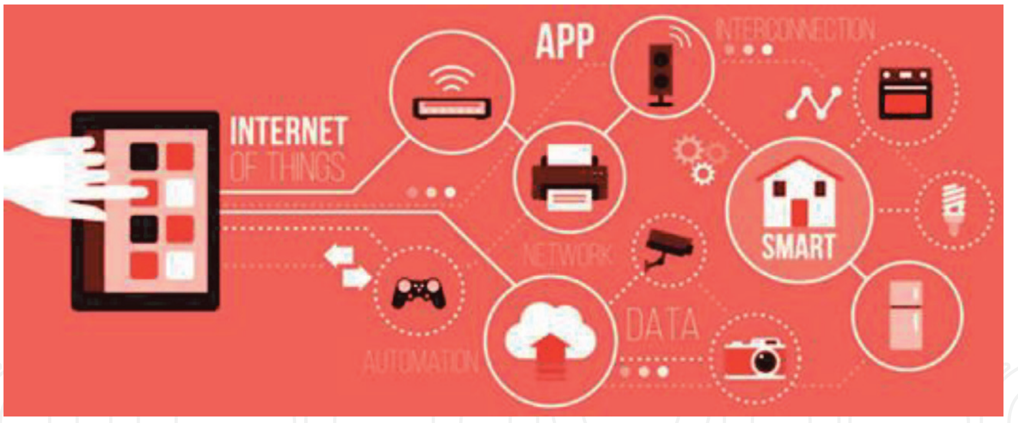

Figure 13.
Basic blocks of IoT.

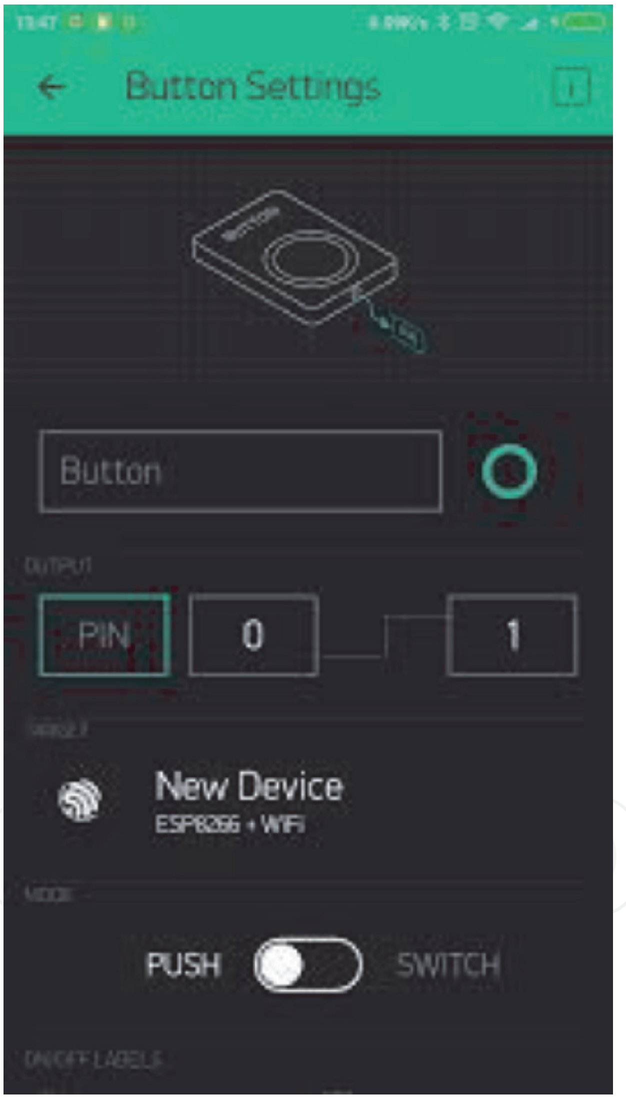

Figure 14.
Blynk platform.

can manage hardware distantly. Blynk server provides control over communication among the smartphone and hardware. It is an open source platform and be able to lever thousands of devices. Blynk Libraries are accessible and designed for almost all hardware platforms. These libraries help to communicate with the server and operate all inward and extrovert commands [14]. By pressing any key on Blynk app on the smartphone, the signal moves to the Blynk Cloud.

4. LabVIEW

LabVIEW is a software improvement environment produced by National Instruments. In order to recognize a real time data acquisition, LabVIEW is introduced. LabVIEW is worned to execute the system. The system investigates level of the entire connected sensor. At first, it was attentive on intriguing measurements from assorted lab instruments; however it has extended significantly from its initiation. LabVIEW is not a coding language, it is a graphical environment. The coding is actually called "G" code. It is a graphical indoctrination language that uses icons as a substitute of lines of text to build applications; it uses a dataflow encoding to resolve recital [15]. This software is straight forward to handle as it does not require an immense programming skills. The benefit of LabVIEW is prompt and uncomplicated erection of the graphical user interface (GUI) that process the refurbishing of parameters (without interfering with the code) and well-designed appearance of results. Tools used in LabVIEW is illustrated in **Figure 15**.

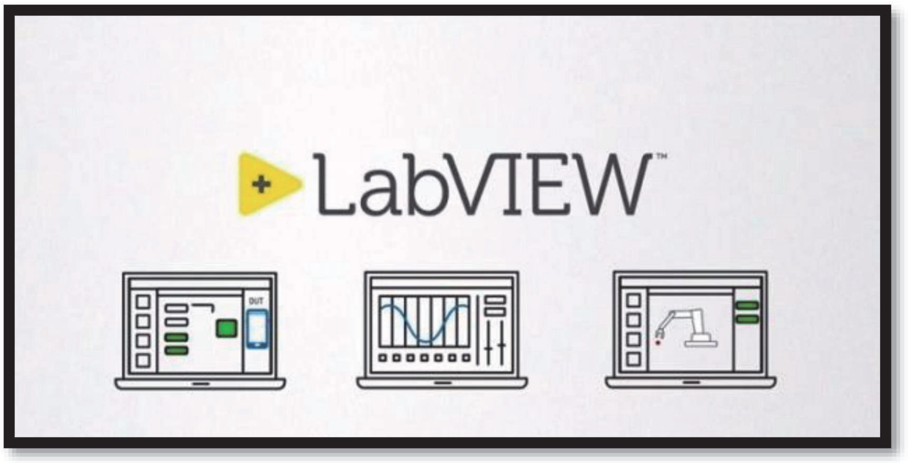

Figure 15.
Toolkits in LabVIEW.

5. Working of the system

The system proposes a design to fit monitoring applications on smartphones. Wireless sensors positioned at planned locations sense the level of carbon monoxide, nitrous oxide, humidity and temperature in the air. It provides simple access to the users to supervise real time air quality in their vicinity. It uses cost-effective and readily accessible devices such as an air quality sensor, carbon monoxide gas sensor, nitrous oxide gas sensor and SY-HS220 sensor. Microcontrollers are used at the sensor node for supervising these sensors. The sink node collects the data from sensor node and transfers it to the cloud database through wi-fi module. In the cloud, the data analysis is done so that the society takes measures to mitigate air pollution.

5.1 Accomplishment of a system to attain a data from sensor node(mote)

The air quality monitoring technique involves an interface among Arduino and LabVIEW software. The received values are keep in an Excel sheet and plotted on a chart. The LabVIEW programming for partition of data from each mote would be executed. The co-ordinator node is interfaced with LabVIEW through VISA

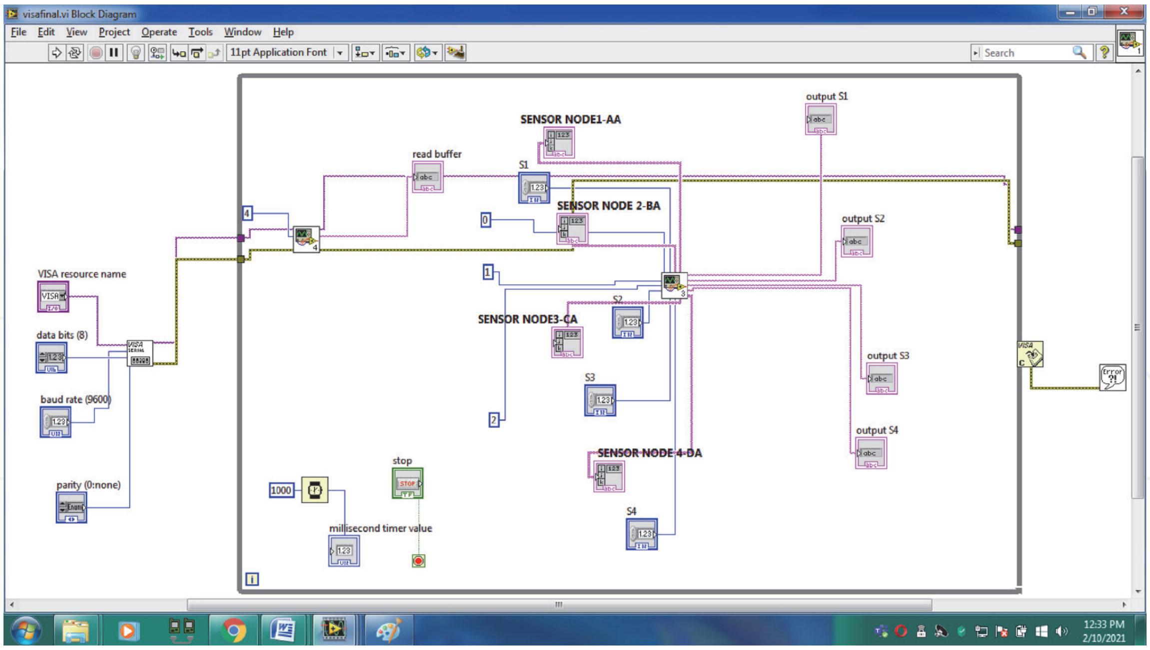

Figure 16.
LabVIEW mote data management.

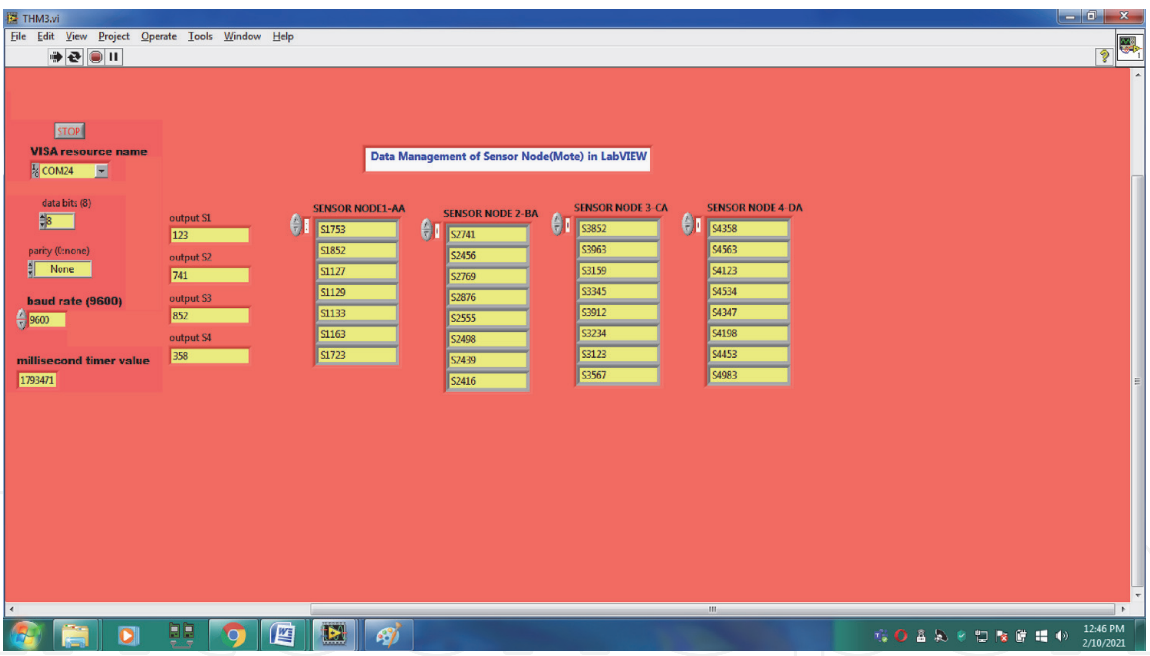

Figure 17.
GUI developed in LabVIEW for mote separation.

function tool [16]. The co-ordinator node collects the data from each mote and separated in LabVIEW and is shown in **Figures 16** and **17**.

6. Comparative analysis of current system with air quality status of Maharashtra 2019–2020 for Solapur City

For comparative study of the current system with traditional system, it has been envisaged one of the regions of Solapur city. Solapur is the fourth major city in the state of Maharashtra which has been racing simultaneously with first, second and third stages of industrial development. Solapur had hit the national headlines for being the most polluted city in India next to surat during 2001.As national ambient air quality standards the solapur municipal corporation has installed electronic sensors to detect SPM-10, SPM-2.5, NOx, SO2, CO apart from temperature, humidity, rainfall etc. Various studies titled "An insight into the unseen: A case study of AAQ in Solapur city [17]", "Air affair in the proposed smart city of Solapur [18]". The finding indicates SPM-10 to be causing worry for the citizen and is largely on the higher side of tolerance limit during the dry months. Various mitigation measures such as plantation, golf courses etc. were proposed. The present

Station name	Year	Month	Average of SO_2	Average of NOx	Average of RSPM
WIT campus	2019	Apr	18	36	82
		May	18	37	86
		Jun	19	38	81
		Jul	19	37	79
		Aug	17	35	75
		Sep	14	33	69
		Oct	13	32	68
		Nov	13	33	67
		Dec	12	32	69
	2020	Jan	12	32	68
		Feb	12	32	71
		Mar	12	32	71

Table 1.
Statistics for monthly average interpretation recorded at WIT campus.

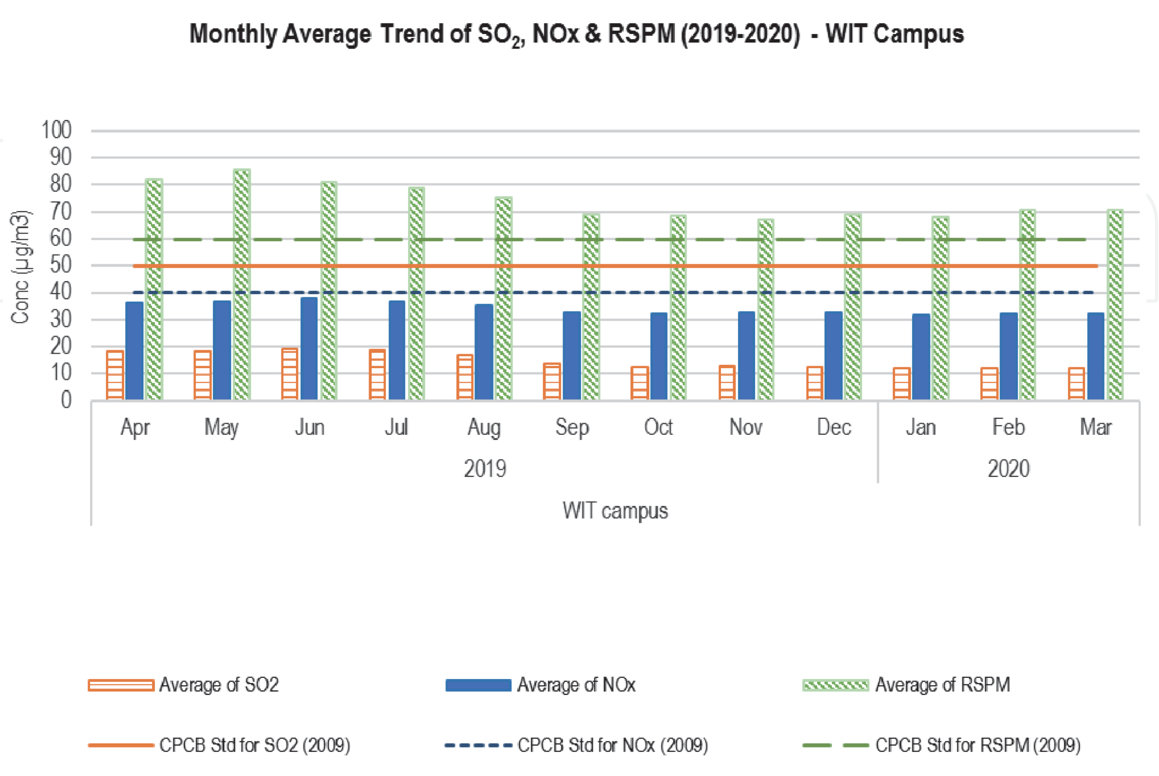

Figure 18.
Monthly standard analysis recorded at WIT campus.

smart WSN and IoT based system be installed at various stations of WIT campus area, collected data and were displayed on Android App developed on users mobile phone, on Blynk Platform, on LabVIEW Front Panel and Arduino serial monitor window. The prime advantage of developed system is that remote monitoring and controlling of air quality has been initiated. The monthly average reading recorded at WIT Campus, Solapur by CPCB (Central Pollution Control Board) is shown in **Table 1**. Its graphical representation is shown in **Figure 18**.

After deploying the sensor nodes at different locations of WIT campus, the data gathered at co-ordinator node is presented in **Table 2**. The proposed system measures the various air quality parameters such as NOx, RSPM, Temperature,

Station name	Year	Month	Average of NOx	Average of RSPM	Average of temp.	Average of humidity	Average of CO
WIT Campus	2019	Apr	38	100	44	28	120
		May	35	95	43	30	118
		Jun	38	88	40	33	115
		Jul	33	78	38	36	140
		Aug	34	72	33	40	100
		Sep	38	70	33	40	90
		Oct	31	69	32	39	88
		Nov	30	63	32	39	83
		Dec	31	68	34	32	79
	2020	Jan	32	69	33	29	78
		Feb	31	69	32	29	75
		Mar	31	69	32	30	75

Table 2.
Statistics for monthly average recorded at WIT campus by co-ordinator node.

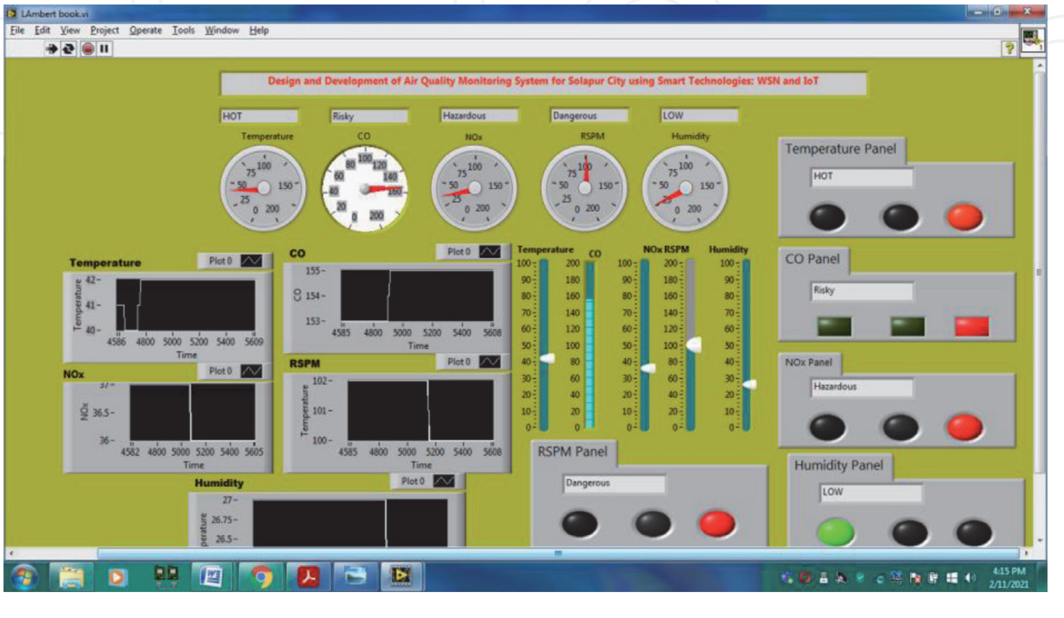

Figure 19.
Graphical user Interface on LabVIEW.

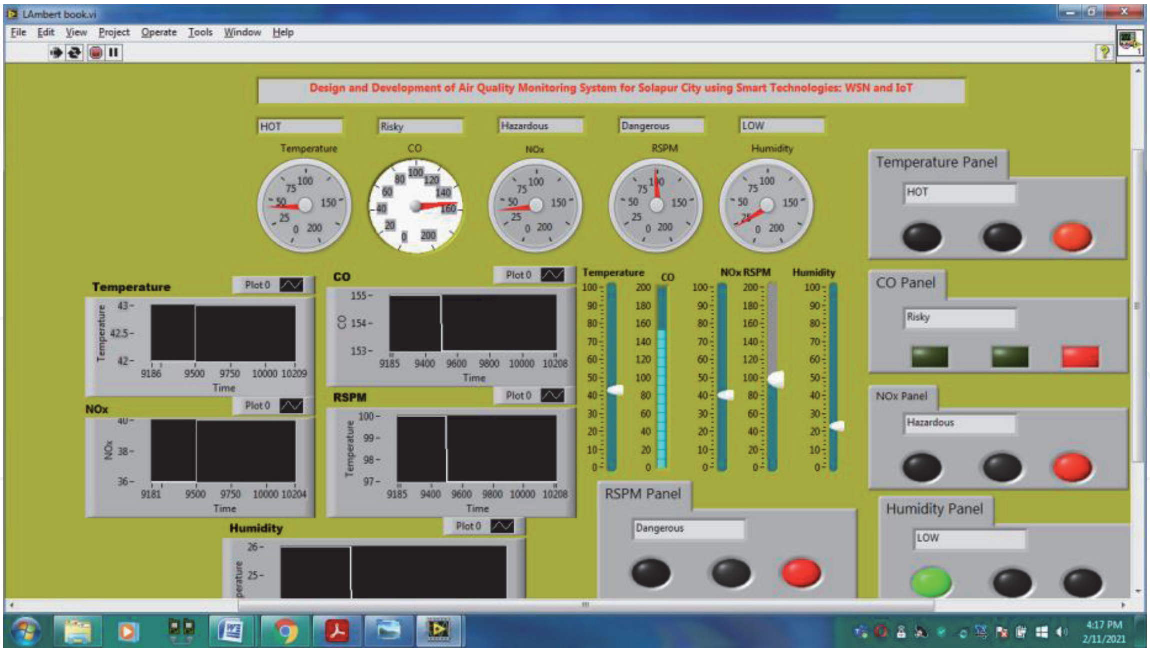

Figure 20.
Graphical user Interface on LabVIEW showing different levels of sensors.

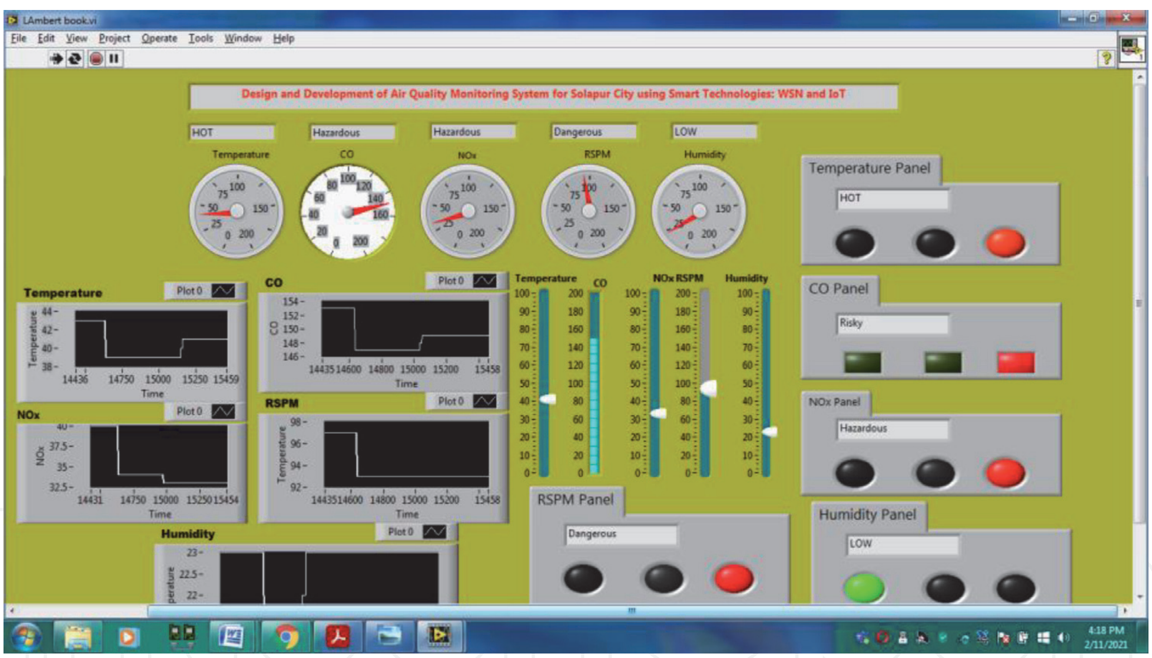

Figure 21.
Graphical user Interface on LabVIEW showing various levels of air quality.

Humidity, CO etc. Their GUI (Graphical User Interface) on LabVIEW is shown in **Figures 19–21**, respectively.

7. Results

7.1 Arduino based results

The results of air quality monitoring system are displayed on arduino serial monitor window of co-ordinator node, Front Panel of LabVIEW and on Blynk platform through the Android app developed by user's mobile phone. Arduino based results of air quality monitoring system are as follows. The sensors calibration and its coding are done in arduino IDE. This is shown in **Figure 22**.

7.2 LabVIEW based results

The LabVIEW front panel will exhibit the responses when the sensor incorporated within the sensor node collects the data within the environment. The threshold frontiers specified for this sensor are according to the OSHA standard. According to the threshold limit, different levels are displayed on the LabVIEW.

The sensors three levels are displayed on the front panel of LabVIEW. These levels are different for different sensors. For temperature sensor, cool level is displayed using green colored LED. Normal level of temperature is displayed using yellow colored LED, while red colored LED shows hot level of temperature. A voltmeter and pollution level meter is given, for easiness of users, to monitor the different pollution level. For CO sensor, Normal level is displayed using green color square LED. Hazardous level of CO is displayed using yellow color square LED, while red color square LED shows risky level of CO. For NOx sensor, normal level is displayed using green colored LED, unhealthy level of NOx is displayed using yellow colored LED, while red colored LED shows hazardous level of NOx. Low level of humidity is displayed using green colored LED. Normal level of humidity is displayed using yellow colored LED, while red colored LED shows high level of humidity. The RSPM levels such as normal, unhealthy and hazardous are displayed using green, yellow and red oval LED's respectively. The rationale of GUI is to erect the system extra interactive and superficial. The programming structure is shown in **Figure 23**. The real execution of wireless air quality monitoring system is shown in **Figure 24**.

7.3 IoT based result

Internet of things (IoT) based system helps to detect the existing level of perilous gases in the environment. The system assists to obtain the data from any locality where the mechanism is installed. All the data can be perceived in the smartphone app. The present system uses the Blynk app. The relevance for the IoT-based air

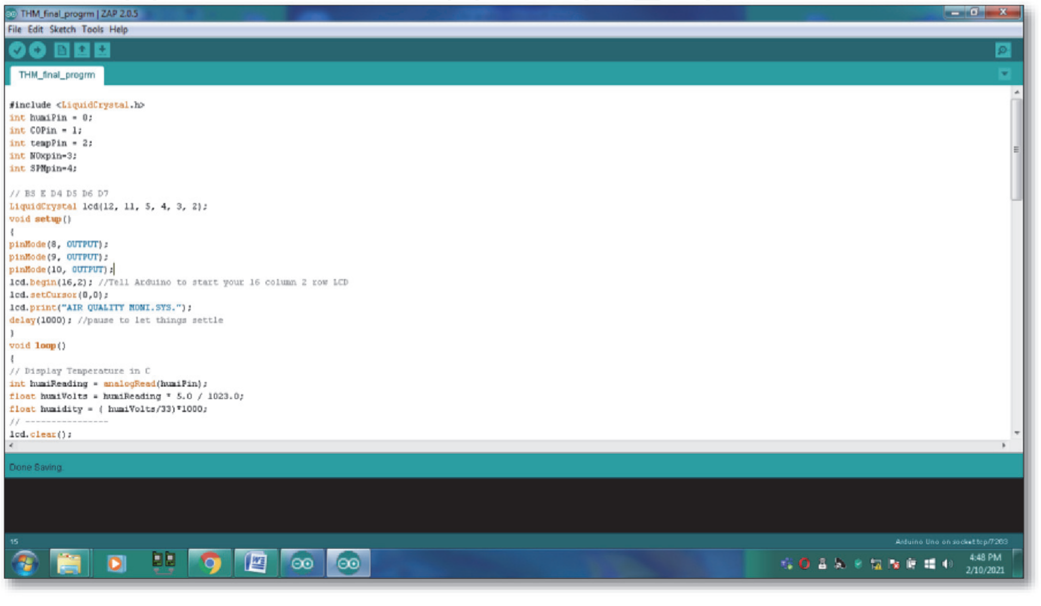

Figure 22.
Arduino coding for air quality monitoring system.

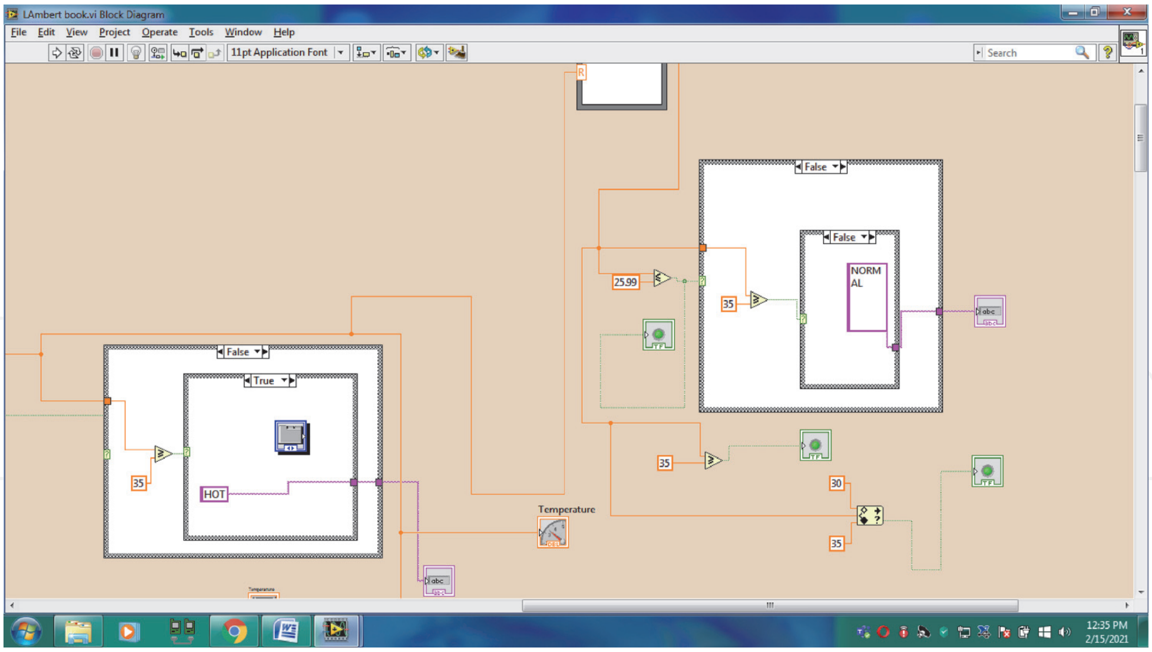

Figure 23.
LabVIEW programming structure of air quality monitoring system.

Figure 24.
Actual LabVIEW G-code for air quality monitoring system.

quality monitoring was evolved to observe the data and be vigilant users. Air quality can be scrutinized together with the web server and with linked smart devices via the application. Monitoring of air quality is effortless and competent using the Blynk App as it provides admittance anytime using smart devices. For IoT enabled system, the user obtains a notice through the Blynk Application on the mobile phone about the detection level of CO, NOx, RSPM, humidity and temperature for the area where the sensor nodes were deployed. An experimental set up for the IoT testing of air quality shown in **Figure 25**.

In **Figure 26**, the Blynk application on a mobile phone shows humidity as 20.9%, temperature as 34.17°C, CO as 44 ppm, NOx as 22 ppm and RSPM as 512 μg/m^3.

DOI: http://dx.doi.org/10.5772/intechopen.98755

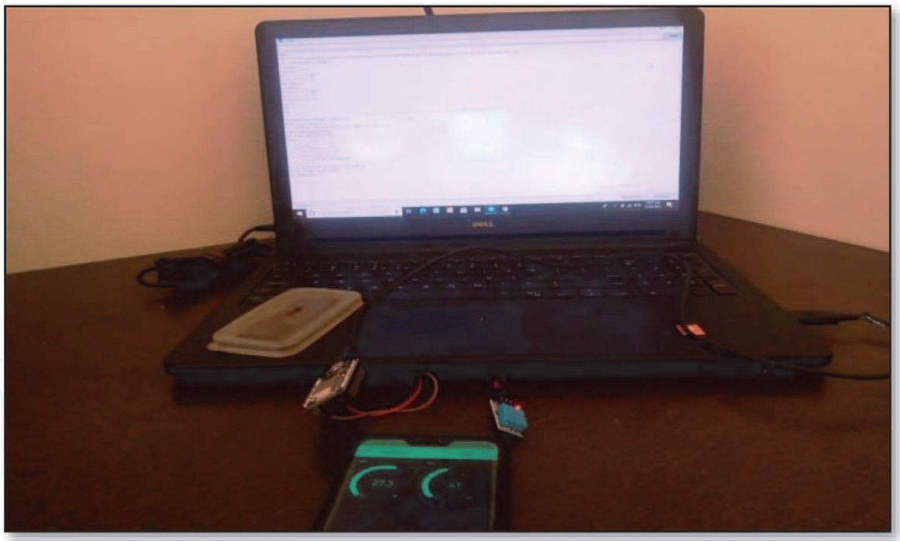

Figure 25.
Experimental set-up for the IoT testing of air quality.

Figure 26.
Blynk app for air quality monitoring.

These real-time values are sent to the app using internet. A warning is sent to the App for alerting the user that the contamination in air is beyond which can be detrimental for human health. Alerting the users is mandatory to avert an environmental impairment and users can take instantaneously remedial measures.

8. Conclusions

This chapter describes a Wireless Sensor Network (WSN) based air quality monitoring system for Solapur city using IoT and LabVIEW. An amalgamation of WSN and IoT makes the system more reliable, smart and scalable than the traditional data logger system. A cost-effective, least power and efficient wireless star network based online air quality monitoring scheme is developed that includes temperature, humidity, RSPM, carbon monoxide and nitrous oxide measurements. The system evaluates the contamination level in the public areas. IoT accredits the users to observe the contamination levels of the region where the system is installed. Moreover, LabVIEW diminish the hardware necessity through visual coding. The real-time data on user's mobile phone can examine to recognize the air quality in the installed area of the system. Due to the use of IoT web platform and XBee wireless protocol, the developed system is less time consuming and less power consuming over to the traditional system.

Author details

Tabbsum Hanif Mujawar[1*], P. Prabhkar[2], Vijendra Chaudhary[3] and Lalasaheb Deshmukh[4]

1 School of Physical Sciences, P.A.H. Solapur University, Solapur, Maharashtra, India

2 School of Earth Sciences, P.A.H. Solapur University, Solapur, Maharashtra, India

3 Dayanand Science College, Latur, India

4 Department of Electronic Science, Savitribai Phule Pune University, Pune, Maharashtra, India

*Address all correspondence to: thmujawar@sus.ac.in

References

[1] R.K. Pachauri, P.V. Sridharan, "Looking Back to Think Ahead, Green India 2047: Growth with Resource Enhancement of Environment and Nature", Energy and Resources Institute, 1998, pp.1-368.

[2] Sengupta R, Madal S, "Health damage cost of automotive air pollution: Cost benefit analysis of fuel quality upgradation for Indian cities", eSocial Sciences, 2005.

[3] Gajul M.D. and Mujawar.K.C Prabhakar. P., "Ambient Air Quality in Solapur; A tight rope walk for Solapur citizens", Indian Society of Geochemistry, 56(2013), pp.1-6.

[4] Muthu Bharathi. M, Rajasekaran. M, "Air Quality Monitoring System Using Wireless Sensor Networks", International Journal of Engineering Research & Technology (IJERT), 6 (2018), pp. 1-6.

[5] Harsh N. Shah, Zishan Khan, Abbas Ali Merchant, Moin Moghal, Aamir Shaikh, Priti Rane , "IOT Based Air Pollution Monitoring System", International Journal of Scientific & Engineering Research, 9(2018), pp. 62-66.

[6] K. Maraiya, K. Kant and N. Gupta, "Application based Study on Wireless Sensor Network", International Journal of Computer Applications, 21(2011),pp. 9-15.

[7] https://www.sparkfun.com/datasheets/Sensors/Biometric/MQ-7

[8] https://www.ti.com/lit/ds/symlink/lm35

[9] http://china-total.com/Product/meter/gas-sensor/MQ135

[10] Margolis, Michael, Arduino Cookbook, Ed. 1, O'REILLY® Media, Inc., March 2011, pp. 81-213.

[11] XBee/XBee-Pro OEM RF Modules, Maxstream, Inc., Lindon, UT, 2007.

[12] M. Benammar, A. Abdaoui, S. Ahmad, F. Touati, and A. Kadri, "A modular IoT platform for real-time indoor air quality monitoring," Sensors, 18 (2018), pp. 581.

[13] Y. J. Fan, Y. H. Yin, L. D. Xu, Y. Zeng, and F. Wu, "IoT-based smart rehabilitation system," IEEE Transactions on Industrial Informatics, 10 (2014) , pp. 1568–1577.

[14] Rucha Golwalkar*1*, Kajal Shivgan*2*, Parul Sindhwad*3**," Pollution Monitoring System Using IoT and LabVIEW", International Journal for Research in Engineering Application & Management, 06(2020), pp.184-188.

[15] Bitter, Rick, T. Mohiuddin and M. Narocki "LabVIEW Advanced Programming Techniques "Boca Raton: CRC Press LLC, 2001

[16] T.H. Mujawar, V.D. Bachuwar, M.S. Kasbe, A. D. Shaligram, L.P. Deshmukh "Development of wireless sensor network system for LPG gas leakage detection system", International Journal of Scientific & Engineering Research, 6 (2015) 558-563.

[17] Bansode. P. B Mujawar. K. C Prabhakar. P.," An Insight into the Unseen: A Case Study of Ambient Air Quality in Solapur City, Maharashtra, India", Jour. Of Environ. Geochem.,15 (2012), pp.43-46.

[18] P Prabhakar, MD Gajul, NT Chavan, "Air affair in the proposed smart city of Solapur–a case study", Journal of Applied Geochemistry, 20(2018), pp.466-473.