RESEARCH ARTICLE

Development of LOCAL-IP based Environmental Condition Monitoring using Wireless Sensor Network

Avijit Mallik[1,*], Shaik Asif Hossain[2], Asif Bin Karim[3] and Shahajada Mahmudul Hasan[1]

[1]Department of Mechanical Engineering, RUET, Rajshahi-6204, Bangladesh; [2]Department of Electronics and Communication Engineering, KUET, Khulna-9203, Bangladesh; [3]Department of Mechatronics Engineering, RUET, Rajshahai-6204, Bangladesh

ARTICLE HISTORY

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Abstract: ***Background & Objective*:** In this paper environment monitoring systems is implemented by using sensors and then send the sensors data are sent to a local internet protocol (IP) using Wi-Fi. For enchanting data, DHT-11 (Temperature and Humidity sensor) and MQ-6 (LPG gas sensor) are being used. The basic objective of this research is to monitor and to develop a real-time monitoring of humidity and temperature, as well as the availability of gas using the very available DHT-11 sensor, MQ-6 sensor, and ESP-8266 NodeMCU module and then observe the data from a local IP based webpage.

***Conclusion*:** This paper also makes a compact distinction between conventional and the local IP based observing system of an environment. The sensor's data are saved in an IP based webpage by which we can monitor the sensor's data without any access to the internet.

Keywords: DHT-11, IP, MQ-6, NodeMCU, Wi-Fi.

1. INTRODUCTION

A wireless sensor network (WSN) is a collection of distributed sensors that observe physical or environmental conditions, such as temperature, sound, pressure and so on. Data from each sensor pass through the network node-to-node. With a vast use in communication networks, these systems are used in object detection [1-3]. At present, the Sensor-based system is becoming very popular in many activities. This is mainly because of the easy availability of sensor and low-cost management, which help us in many ways. In fact, the use of such systems is diversified from monitoring of network cardinality to biomass estimation [4, 5].

Almost in every administrative or nursing work sensor is a pressing need. So, nowadays, people want to control their work through an automatic sensor-based system or automated system. However, environmental monitoring is the prerequisite of ecosystem-based research and activities. For environmental data observation which is subjected to constant monitoring; a real-time monitoring of data for the environment is very necessary [6-8]. In this paper, a research has been conceded out to monitor the real-time condition (Humidity and Temperature to be more precise) through a local IP without the access of internet, because of security reason and so on; in which physical presence is not needed. Therefore, it can save time and can be a very effective way of monitoring. This research has been directed using very modest methodology and appliances which are available and require minimal technical knowledge to operate. DHT-11 is a type of sensor which can detect the temperature and humidity of its surrounding atmosphere and it is available almost everywhere in the world. Combining the results with MATLAB environment, the upcoming data can also be forecasted through the basic knowledge of MATLAB or other engineering and scientific software. Arduino is a really good and easy to use hardware these days; this also has an individual IDE named as the same hardware. However, using an Arduino board is not necessary for just monitoring services, because of cost management and time consumption. Node MCU is a kind of component that consists of an ESP8266 Wi-Fi along with a microcontroller with 1 analog and 12 digital pins, for which it is more efficient than an Arduino board and the data rate is also effective for this module.

In past ages, radio frequency identification (RFID) was utilized to send and receive data from the system. Recent days, RFID is not used because of security manners. Such RFID systems require copious protocols [9, 10]. Hence, protocol complexity is a common impediment in this technique. An HTML webpage is also shown in this paper for the purpose of real-time data monitoring from the sensor. Fig.

*Address correspondence to this author at the Department of Mechanical Engineering, RUET, Rajshahi-6204, Bangladesh;
Tel: +880-1777-678831; E-mail: avijitme13@gmail.com

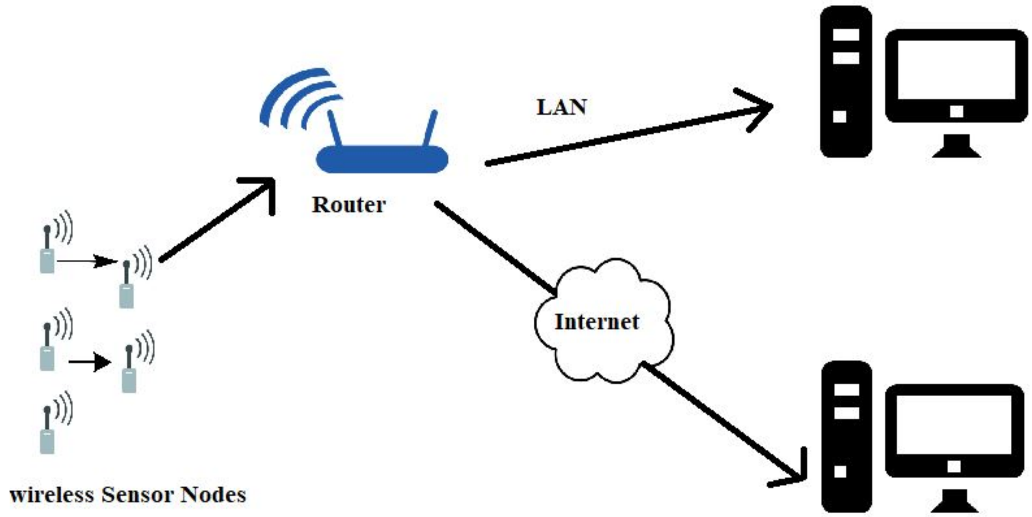

Fig. (1). Wireless Sensor Network (WSN).

Table 1. List of materials along with stipulations and cost estimation.

Experimental Setup				Conventional IoT Setup			
Product Name	**Voltage Rating**	**Current Rating**	**Price (BDT)**	**Product Name**	**Voltage Rating**	**Current Rating**	**Price (BDT)**
Bread-Board	5-30V (DC)	10 A	90	Bread-board	5-30 V (DC)	10 A	90
Jumper Wires Set	-	10 A	120	Jumper Wires Set	-	10 A	120
4 Channel Re-lay	5V(DC)/250V (AC)	5-10 A	400	4 Channel Re-lay	5V(DC)/250V(AC)	5-10 A	400
NodeMCU v1.0	5-12V (DC)	2.1 A	600	Intel Gallieo	12 V (DC)	2.1-4 A	13,500
DHT-11	3.3-5V (DC)	200 mA	150	DHT-22	5 V (DC)	200-500 mA	700
MQ-6	3.3-5V (DC)	200-300 mA	300	TSG (Taguchi)	5 V (DC)	250 mA	1450
IR Photodiode	3.3 V (DC)	500 mA	15	IR	3.3 V (DC)	500 mA	15
		Total	1,675			Total	16,275

(**1**) represents a schematic of local IP based wireless sensor network.

2. MATERIALS AND METHODS

2.1. Materials

In this research, the Arduino based ESP-8266 based NodeMCU was used. The various data attainment system of Arduino or Raspberry-pi is mother controller but using NodeMCU gives the benefit of using an Arduino along with a 2.4 GHz Wi-Fi module. As this was a demo project and needed far more inquiry in the real practice so, breadboards and jumper wires were used to test the tasks. The bill of materials used for this research is given below along with specifications in Table **1**.

From, Table **1**, it is very clear that this experiment costs about 10 times less than the conventional IoT setup. So, in terms of cost, this system is no doubt veryfeasible.

For smoke detection, it is very necessary to measure its concentration within the experimental plant. Thus, MQ-2 gas sensor is a very fine one as from its datasheet it is known that this SnO_2 based semiconductor sensor is very sensitive to the smoky environment. It gives a reading within 1024 or 2^{10}, which can be easily converted to ppm value by further analysis.

Humidity is defined as the amount of water vapor contained in air. Usually, it is expressed as absolute humidity, dew point, and relative humidity. The sensor used in this research, DHT11, is designed to measure humidity in terms of relative humidity (RH). Relative humidity (RH) is the ratio of the amount of water vapor content of the air to the saturated moisture level at the same pressure or temperature:

$$RH = \rho w \ \rho s \times 100\ \% \quad \text{(i)}$$

Here, RH is comparative humidity, ρw is the density of water vapor, and ρs is the density of water vapor at soaking.

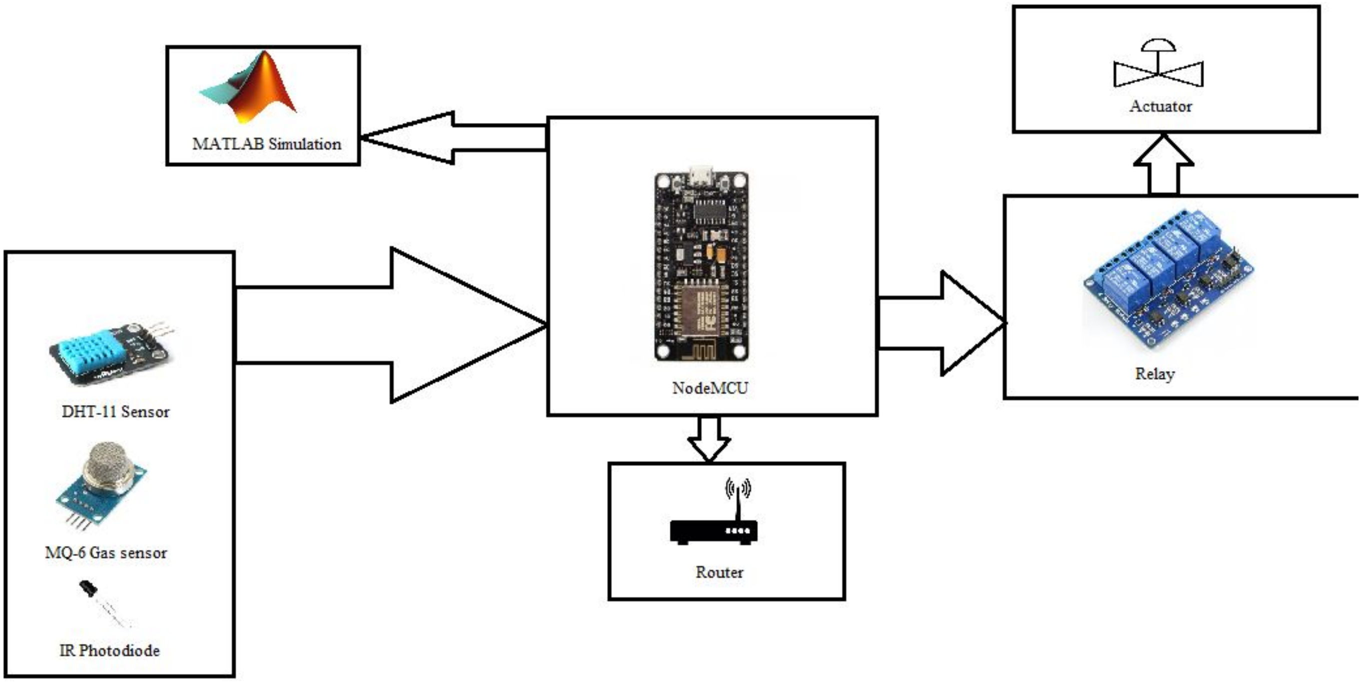

Fig. (2). System architecture.

The sensor DHT11 detects moisture in the air by measuring the electrical resistance between electrodes. It is fabricated with a moisture holding substrate. When substrate absorbs moisture, ionization takes place and results in the increase in conductivity between the electrodes. The relative humidity is proportional to the change in resistance between electrodes due to moisture absorbed.

An IR sensor is a device, which consists of a pair of an IR LED, and a photodiode, which is collective, called a photo-coupler or an optocoupler. The IR LED emits IR radiation, reception, and intensity of reception of which by the photodiode dictates the output of the sensor. Table **2** shows the Optimal conditions for the sensors used.

2.2. Methodology

The procedure is divided into dualistic basic parts, hardware and webpage-based methodology. Firstly, the hardware setup was completed. The construction between NodeMCU, DHT-11 sensor and the MQ-6 sensor was done using conformist methods.

3. SYSTEM ARCHITECTURE

This research discusses one of the implementations of a system using Wireless Sensor Networking (WSN). The multi-sensor system consists of distinct subsystems: WSN (Wireless Sensor Network), GUI (Guest User Interface), Relay switching for actuators and sending of the data to the local IP as it is shown in Fig. (**2**).

MQ-2 gas sensor and IR photodiode are used to determine smoke/gas concentration and fire presence respectively. As the gas sensor works fine within temperature ranging 25-35 ^{0}C & RH ranging 55-70%, so DHT-11 sensor is used to check the temperature and relative humidity level of the experimental plant. Further mathematical modeling and analysis are done for the steady-state design of the experimental system. After that acquisition of those factors which combines a threshold, value has to be set for controlling the total system modeling. From the datasheet of DHT-11, MQ-2 and IR photodiode, parameters and the operations are obtained. The DHT-11 sensor is a digital sensor with digital output data, which combines Integrated Circuits, is the reason behind the direct values of relative humidity and temperature can be obtained. The optimal conditions of used sensors are listed below in Table **2**.

4. NUMERICAL ANALYSIS

As the system focused on gas concentration-based alerting and control appliances, thus only MQ-2 gas sensor calibration is considered for the mathematical analysis. The DHT-11 sensor is used to check the conditional Temperature (25-35 Deg. C.) and Relative Humidity (55-75%). From gas sensor's sensitivity calculations we get:

$$R_S = [(V_c . R_L)] - R_L \quad (1)$$

where, V_C = Supply voltage = +5V; R_S = Sensor Output Resistance; R_L = Load Resistance; V_{RL} = Sensor Output Voltage. From, the equations of analog signals of 1024 (2^{10}) resolutions; Gas Sensor's Sensitivity = R_{S0}/R_0; R_{S0} = Sensor Output Resistance at the normal environment; R_0 = Sensor Output Resistance at ideal environment (1000 ppm of LPG, 25 Deg. C. & 60% RH). In this study, at 27 Deg. C. & 67% of RH environment [Sensor Sensitivity, R_S/R_0 = 8.71 (at normal room condition)];

So, Gas Concentration (ppm),

$$C = \left\{Log_{10}\left({R_s}/{R_0}\right) - b\right\} / m \quad (2)$$

Table 2. Optimal conditions of experimental sensors [3-5, 10-12].

Sensors Used	Optimum Conditions
(MQ-6) Gas sensor	Temperature = 25-350C, RH = 40-80%, PPM threshold ≤ 10000 ppm
(DHT-11 Sensor) Temperature and Humidity sensor	RH threshold ≤84%, Temperature threshold ≤ 550C, should keep out of magnets (Magnetic resonance affects its value)
(IR photodiode) Light sensitive sensor	Very sensitive to infrared radiations, Detection range up to 5 meters radius. The magnetic field causes scattering.

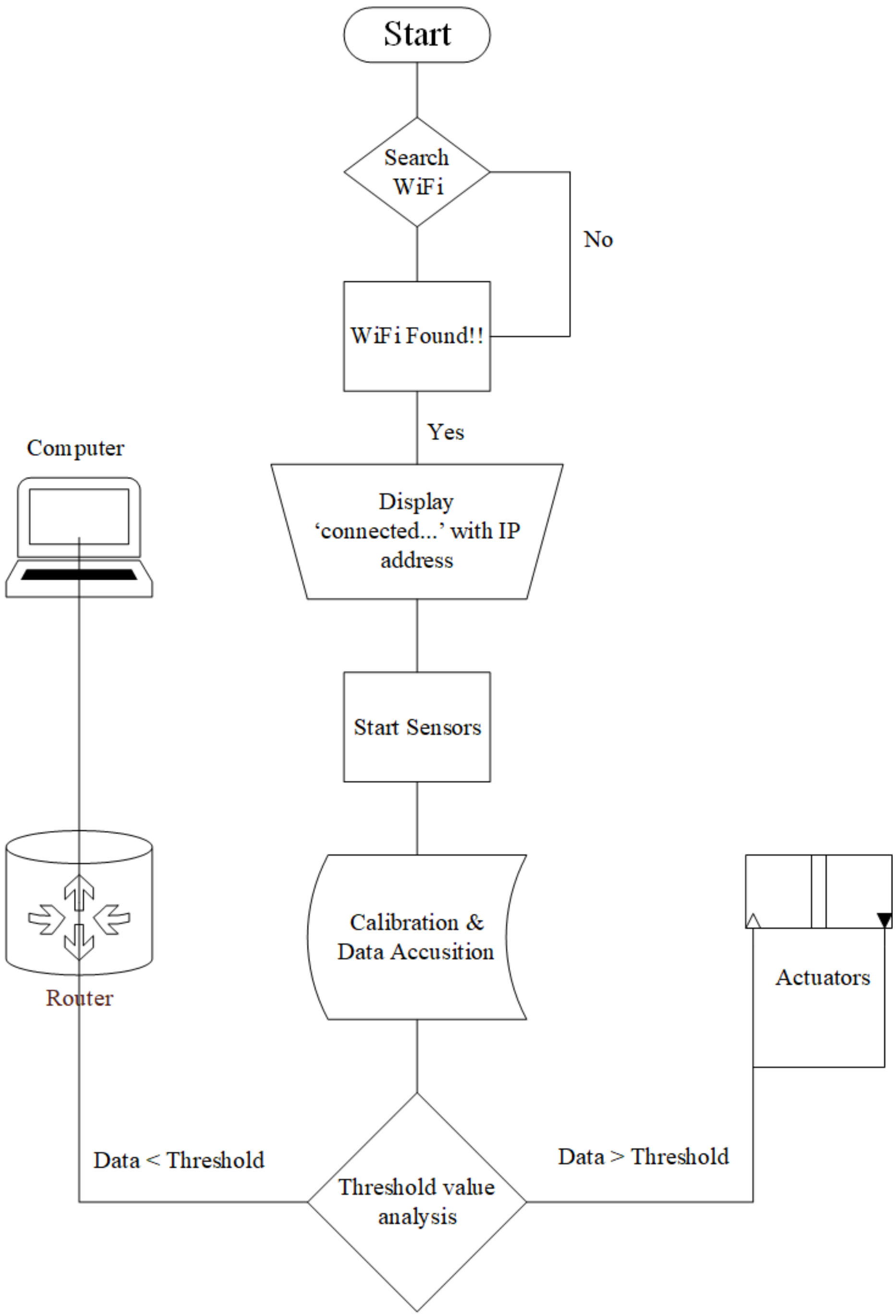

Fig. (3). Flowchart of the monitoring system.

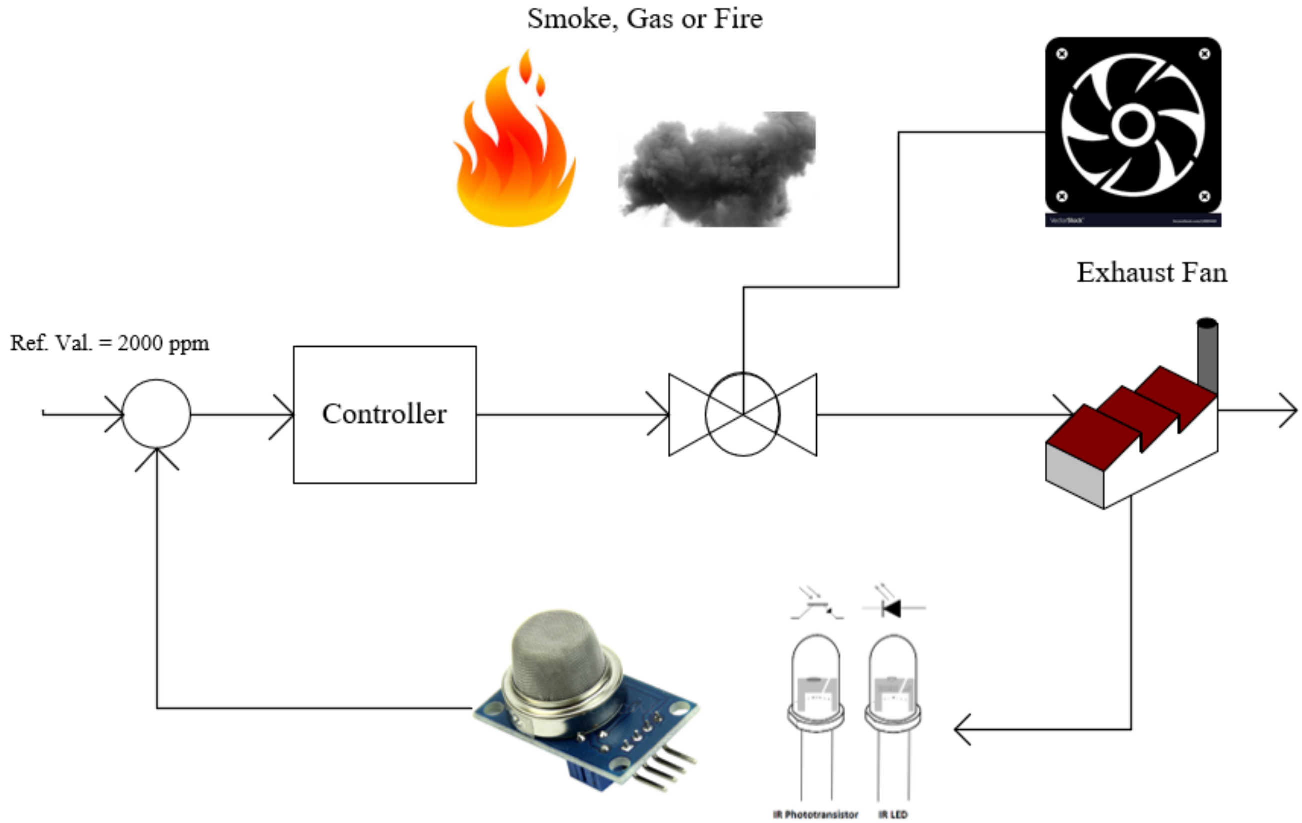

Fig. (4). Schematic of the feedback control mechanism for the system.

Here, R_s/R_0 = Sensitivity of the gas sensor; b = Interception from the Y-axis (From, MQ-2 Sensor datasheet Sensitivity *vs* Concentration graph); m = Slope of the line (From, MQ-2 Sensor datasheet Sensitivity *vs* Concentration graph). Using equations (1) & (2) the smoke concentrations in ppm (parts per millions) can be obtained.

5. SYSTEM ALGORITHM

Firstly, when the Node MCU is turned, it first runs the program compiled in it and starts calibrating the sensors. On concluding calibration, it first goes to connect the local server *via* triggering its Tx and Rx. Now, two types of conditions are relevant; at calibration, the controller detects any problem in sensor value then it sends a signal to the control unit and commands it to make an action. Next, it starts recalibration and if no defect is found then it tries to connect the hotspot which is specified in the program and it checks for the preprogrammed SSID and if found nearby then the connection is created and an IP address is obtained. After connecting to the internet, it tries to connect with the prespecified Local IP. Then the controller creates a data transmission network between the sensors and the IP. Data from the sensor are transferred to the server. The system flowchart is shown in Fig. (**3**).

6. CONTROL OPTIONS

Although great leap has been made in the control area, the precision motion control is challenging the control engineering to a greater extent. The control engineer needs to design a suitable controller which will effectively achieve the desired system characteristics, such as high precision, high speed requirements in precision motion control. Monitoring activities is of key importance for both ecological and environmental activities [13-15]. Feed forward is a term describing an element or pathway within a control system which passes a controlling signal from a source in the control system's external environment, often a command signal from an external operator, to load elsewhere in its external environment. Feedback control deals with any derivation from desired system behaviour by measuring the system's variable and react accordingly. Till today, there are too many control schemes which have been proposed by researchers [16]. In this research, both feedback and feedforward methods of control have been applied.

6.1. Feedback Control for the Controller

In this system, the reference value is set at 2000 ppm of smoke concentrations. Whenever the controller gets a reading higher than 2000 ppm from the gas sensor then it automatically activates the actuators and the rise in concentration gets mitigated. Thus, the error in the system is eliminated very soon after it takes place in the plant. Fig. (**4**) shows the schematic of the used feedback method of control for the proposed system.

6.2. Feedforward Control for the Controller

For the feedforward control, when any abruptions take place in any sensors, then it is very necessary to mitigate the

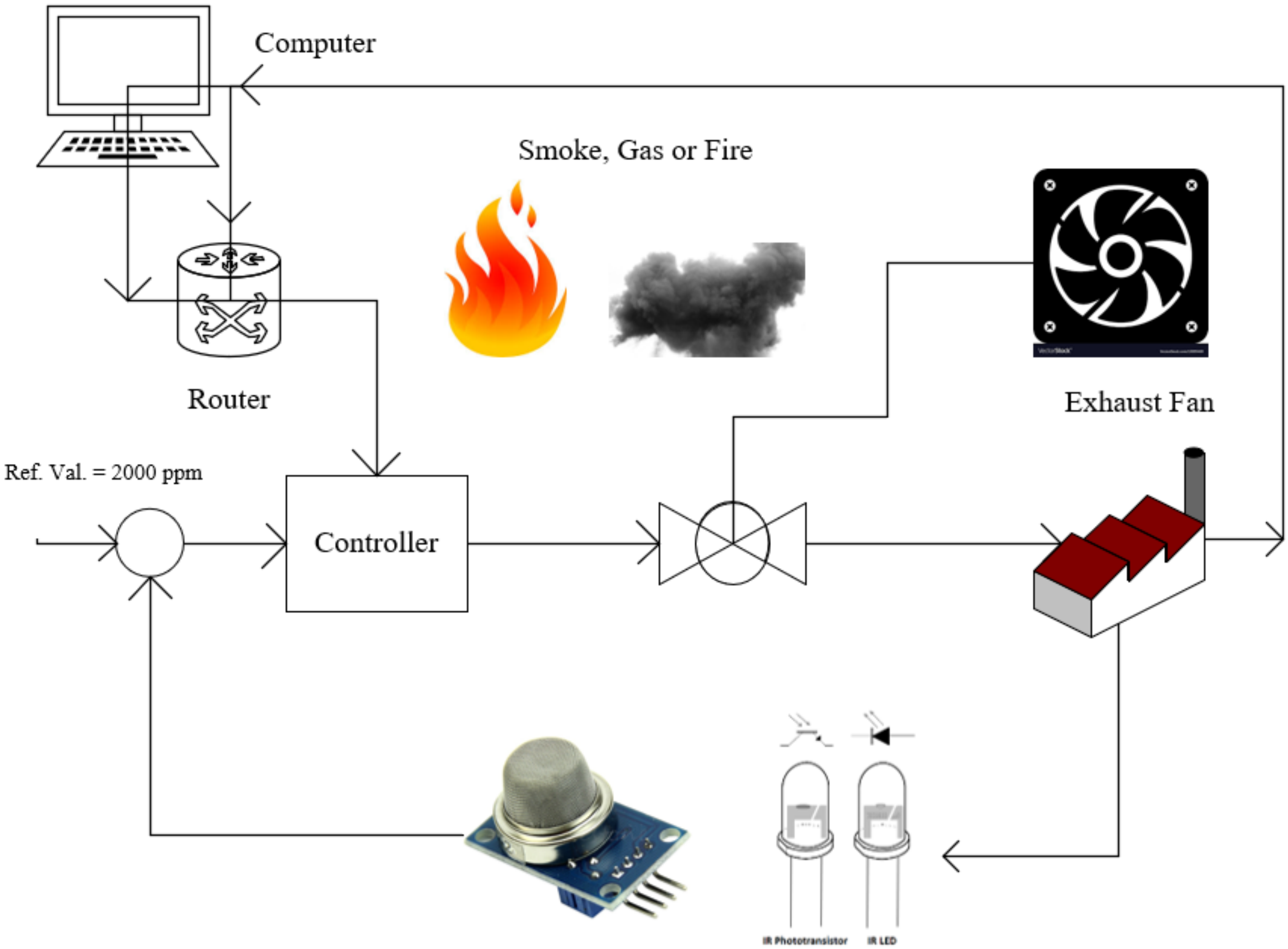

Fig. (5). Schematic of a feedforward control mechanism for the system.

error before it takes place in the plant [16-18]. Thus, manual wireless switching is introduced here to control the abruptions. From the computer, the actuation signal buttons are pressed from the webpage which in regards sends a signal to the controller *via* a routing media (for this experiment a 300 mbps router is used). When the signal is received by the controller, a swift actuator switching takes place to mitigate the abruptions. Fig. (**5**) shows the graphical representation of the proposed feedforward control system for the experimental setup.

7. RESULTS AND DISCUSSION

The records were maintained approximately for a couple of hours. At first, the electronic sensors first gave random data for some error, but consecutively on the state for a periodic time disregarded this error. The data were taken from Arduino serial monitoring directly andthe HTML webpage. Fig. (**6**) shows the screenshot image of the designed webpage using LAN (Local Area Network).

The signals from sensors were processed and analyzed using the MATLAB environment. Fig. (**7**) shows the graphical presentation of captured data for analysis. The data was collected approximately for four hours. The electronic sensors first give arbitrary data for some time, but by running those on the state for a long time eliminates this defect. For better accuracy. The following figures show the graphical presentation of the robust control system.

CONCLUSION

In this work, the main concern is to construct a local IP based environmental data monitoring system. This system is much more efficient than conventional IoT system. In IoT based system, it takes 13 to 17 seconds approximately for sending data but data is transferred about a few milli-seconds in this system. Internet access is not necessary for the system, that's why the data security of the system won't be a major issue. This system requires low-cost management comparing the other system cost, which is shown in the section of the bill of materials.

AUTHOR CONTRIBUTIONS

The experimentations and data analysis along with the system design were performed by the 1st and 2nd authors equally. The 3rd author helped the authors to complete all the experimentations and analysis and the 4th author directly supervised the project.

Fig. (6). User interface design.

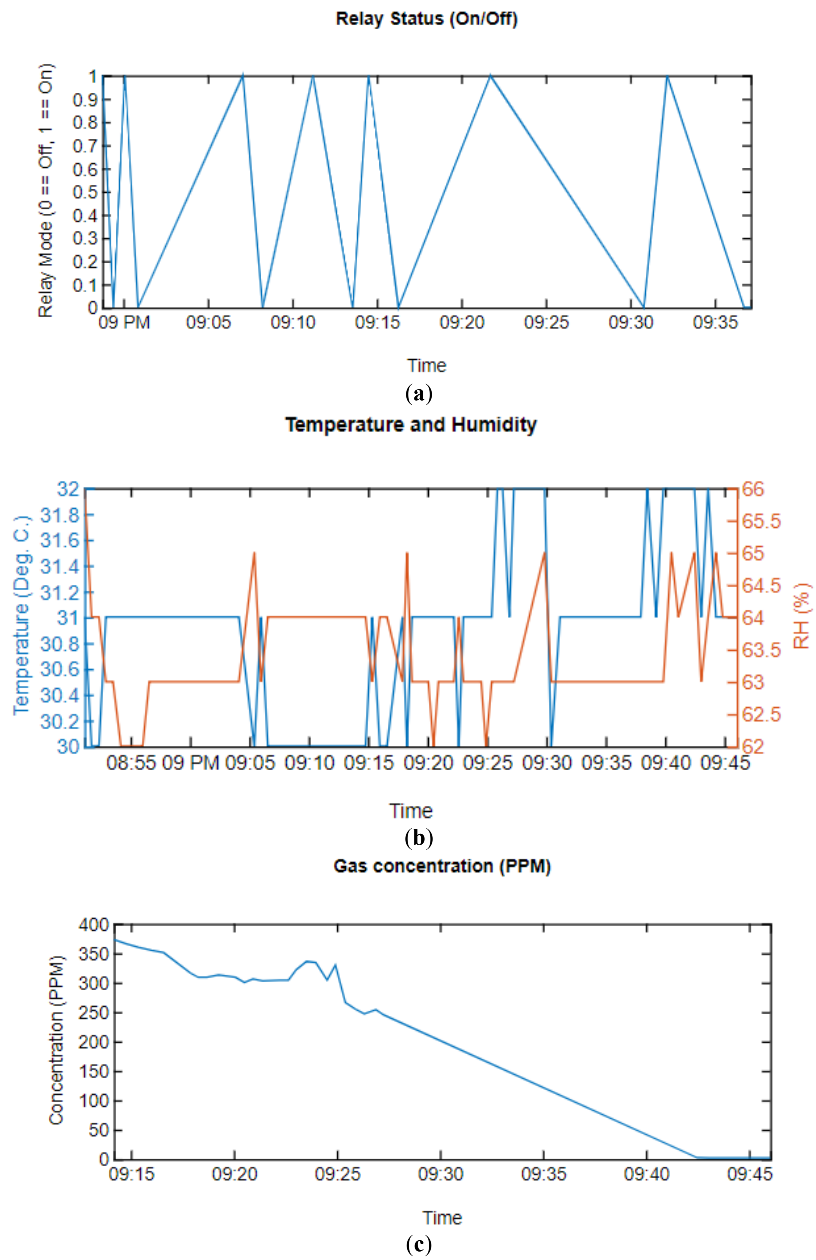

Fig. (7). Graphical presentation of monitored data (**a**) Relay state, (**b**) Temperature and Humidity data logging & (**c**) Gas concentration in the Smoky environment.

CONSENT FOR PUBLICATION

Not applicable.

CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

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