Wireless Sensor Network for Environment Monitoring

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Abstract : Over few years the research carried by academicians led us to implement Wireless Sensor Networks in various scenarios. One such field of implementation is monitoring the environment. As we know polluted, dim lighted and extreme condition such has high pressure or temperature in living spaces has direct impact on individuals residing there. A few systems are developed to measure certain specific parameters of environment. However, we have designed and developed a wireless sensor network system that measures different environmental parameters such as indoor light intensity, air pressure, carbon monoxide levels, gas levels, temperature and humidity. Sensor nodes are placed in the room and hallways, sink node processes incoming data displaying it locally and remote computer with internet access displays these data from cloud to end users.

***IndexTerms* - Environment monitoring, wireless communication, cloud, sensor network**

I. Introduction

The living spaces around us is getting worse day-by-day with pollution. It possesses great danger to our kids. There is lot of air pollution within our home that we barely know about and its risk to health is far greater than we can imagine. We spend almost 90% breathing the indoor air, which is recycled continuously which indeed cause the air to trap and build pollutant. Indoor air pollution causes short- and long-term health issue which leads to decreased productivity, absenteeism and possible litigation. Common symptoms associated with poor indoor air quality are eye, nose and throat irritation, headache, nausea, dizziness and fatigue. Regular exposure to indoor air pollution lead to acute respiratory illness such as asthma, lung cancer, pneumonia, systematic hypertension, chronic obstructive pulmonary disease, Legionnaires disease and humidifier fever. Factors contributing to poor indoor air quality (IAQ) are improper and inadequate ventilation, wood and coal stoves, non-vented gas heaters, tobacco smoke, vehicle exhaust emissions, building materials, carpeting, furniture, maintenance products, solvents, cleaning supplies etc. External factors such as poor ventilation, humidity and temperature can amplify the concentration of indoor pollutants. Some major indoor air pollutants are carbon dioxide, carbon monoxide, ozone, nitrogen oxides, total suspended particulates, formaldehyde, biological agents, radon, lead and asbestos. Therefore, it's very important to monitor pollution levels among our living spaces.

Light is crucial to maintain health and wellbeing of people. Proper lighting can connect us, make us feel good and even enhance our performance. Some research has concluded and light can meet our visual and nonvisual needs. Light also affects our circadian cycle. The light intensity in living spaces is mixture from daylight and artificial lightings like tube light and bulbs. The indoor light intensity is mostly determined by the outdoor weather conditions. People don't complain if the light intensity is good, their eyes will have discomfort from the glare and poor light intensity thus they start complaining. Poor lightings usually compromise on the work people need to perform as it leads to headache, general fatigue, neck or back pain and fatigue in eye muscles. In order to not let the outside polluted air, get in the living rooms of homes it's very important to keep the pressure inside the house at a positive level. Indoor air conditioning removes moisture from air and makes the environment dry. During warm weather condition the high humidity levels risk making a breeding ground for molds, which could cause health problems and property damages. There is also a concern of high temperature within homes as that won't give a good sleep, thus maintaining an ideal indoor temperature is crucial. Thus, high humidity and temperature is a risk for higher levels of indoor pollution.

For human beings to live and work in a supportive and clean environment is vital for health and also productivity. We can monitor our surroundings and living rooms for any pollution. This can be achieved by a bunch of devices that are readily available in the market. These devices can only read pollution parameters of individual room, it won't be able to justify its readings. Therefore, we need to build device having the capability to sense the surrounding and living spaces of not just one particular area but of the whole campus or house. This could be achieved by using wireless transceivers on the sensing devices. Sensing devices comprise of sensors for measuring parameters such as CO, temperature, humidity, CO_2 etc. If we club together these sensors and make it communicate wirelessly, we could achieve pollution monitoring in different areas such as kitchen, sitting room, balcony, cellar, attic, living room etc. Wireless sensor network (WSN) system is the solution for monitoring pollution levels. WSN comprises of many sensors which are deployed at a large open or indoor area and these sensors are connected to each other wirelessly. These sensors can be deployed in an ad hoc manner or pre-planned manner. In ad hoc deployment the sensors are simply dropped off the planes. These sensors measure temperature, pressure, humidity, pollution levels of different kinds, light, sound, rainfall etc. There is 1 to n numbers of sensor network at a given geographical area and these networks communicate with the control center via gateway and sink node. The sensor senses the environment and the data is relayed through sink node to the gateway node. Gateway node receives data from different sensor networks, it has the capability of processing these data and relaying the information to control center and stores data in a server or cloud.

The rest of this papers is structured as follows, Section II presents the literature survey, Section III describes the hardware architecture, Section IV shows the software of system, Section V presents the result and Section VI concludes this paper.

II. Literature Survey

Real time monitoring of carbon dioxide levels in living rooms is possible by using WSNs as stated in [1]. Modern day building structures are made with limited ventilation system in order to make it energy efficient, this reduces the IAQ for the occupants, which is a major setback for health and wellbeing. WSN is implemented here, where each node in network has two antennas and it uses the cognitive networking technique in order to limit interference with other systems in the monitoring area. When we compare a regular WSN and a WSN with opportunistic and cognitive principle, the WSN with opportunistic and cognitive principle is better at packet delay. The opportunistic routing enhances the network performance by limiting the dynamic changes on the network. Another factor that causes poor IAQ is volatile organic compounds (VOCs) as stated in [2]. Thus, a WSN system to monitor VOCs is designed here. VOCs are also a cause of concern for a better health for occupants. In order to make the WSN system utilize minimum amount of power, ZigBee WSN based monitoring system is developed and also the sleep state of sensor node is monitored. This system hardware collects both local and remote VOC concentration measurements. This system's multilayer hardware and software application make it possible to incorporate several numbers of sensors, it also can measure indoor parameters like humidity, temperature and power consumptions, which is essential for such a system. This system can measure the VOC level with high accuracy. Another study [3] tells us that poor IAQ leads to sick building syndrome (SBS), which could be averted by monitoring certain parameters that's causing pollution. A small battery powered system which monitors carbon dioxide levels, temperature, humidity, light intensity and pressure is developed. The system sends the measured data using Wi-Fi. WSN, IoT and cyber-physical system can use this system as a monitoring component. The battery backup of this system was tested to last for three years on continuous operation. According to [4] growing pollution level has brought in rapid climate changes and deteriorated air quality which needs to be monitored on real time, thus, a WSN system is developed to measure seven types of gases such as ozone, particulate matter, carbon monoxide, nitrogen oxides, sulfur dioxide, volatile organic compound and carbon dioxide. This sensor node with so many gas sensors still has provision to add additional gas sensors if demanded by situation. Some algorithm is developed to reduce the energy consumption and increase the monitoring accuracy of this WSN system. In [5] an industrial WSN (IWSN) is discussed, where it emphasizes that indoor WSN doesn't have a reliable wireless communication thus, sensor data never reaches base station. This sort of unreliable communication can be handled by using medium access control (MAC) protocol and cooperative WSN mechanism. IWSNs consists of small cooperation groups of sensors, this sensor nodes shares its information with others and a cooperative data packet is sent to base station. This system gives correct probability of state of machine in an industry, it reduces the probability of false alarm and reduces the energy consumption.

In [6] indoor contactless healthcare monitoring system suffers from critical limitations at present thus, a system is developed for noninvasive fall detection and tag less localization combining radar, ZigBee, micro controller and data processing techniques. This system addresses practical problem such as backscattering and crosstalk in wireless communication. Nuclear facility is very sensitive place and it needs monitoring round the clock for health of the infrastructure and workers there, safety and surveillance thus, a WSN system as discussed in [7] is installed on nuclear facility. A low-cost ZigBee WSN to monitor real time radiation levels is developed, this wireless link is robust and reliable with 100% packet reception. To increase the coverage area high power transmitting nodes are recommended in the system. WSN for Urban Transportation (WSN-UT) is discussed in [8] were a WSN architecture framework for UT is developed. This framework is characterized by flexible configuration, reliable transmission and easy integration with any communication system for urban intelligent transportation system (ITS). This framework eliminates the redundancy and reduces the amount of transmitted data. WSN can also help to monitor underwater erosion mainly happening in coastlines as discussed in [9], here the requirement of WSN is not just to monitor the visible areas but also to monitor underwater environment and this monitoring systems should be able to monitor for long duration with minimum human intervention. In [10] a wireless smart home system is developed which is, flexible and convenient and it gives provision to control remotely. Here smart home is achieved by combining ZigBee, sensor alarm system and image monitoring system. Portable real time air and water monitoring system is discussed in [11], this wireless system is cheap, portable and has comparable accuracy with commercially available devices. Underground and subway has lot of pollutants which affects human health thus, a system which combine environmental sensors is designed in [12], it continuously measures PM_{10}, CO_2, temperature and humidity in tunnels.

In this work, we proposed a WSN real-time monitoring system for measuring the parameters like light, pressure, carbon monoxide (CO), gas such as ammonia (NH_3), nitrogen oxides (NOx), benzene, smoke and carbon dioxide (CO_2), temperature and humidity. Each of these sensors are attached to the node and the data is relayed to base station which processes these data and displays on liquid crystal display (LCD) and further stores in cloud. Finally, this cloud gives a graphical view of the data.

III. Hardware Architecture

In this section, various modules of the introduced system are discussed. The proposed system has three nodes namely node 1, node 2 and node 3. Each of this node attaches sensors to measure two parameters like node 1 measures light and pressure, node 2 measures CO and gas and the last node, node 3 measures temperature and humidity. All the data are processed at base station and the cloud shows graphical interface for easy monitoring. The communication between sensor node and sink node is happening by ZigBee protocol. The communication between sink node and cloud is through Wi-Fi. Additional sensors can be interfaced at sensor node at any given time to increase the application requirement of this system.

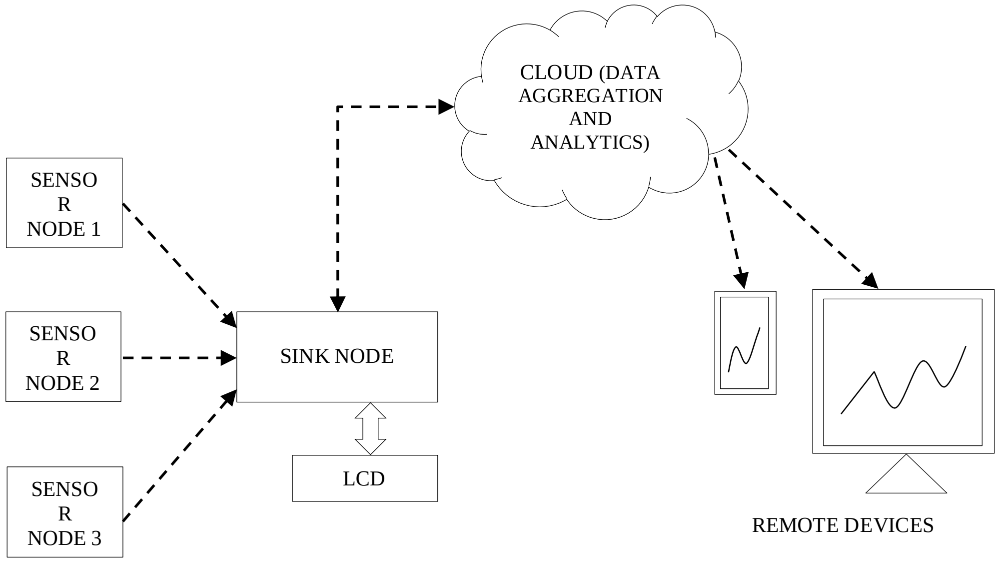


Fig. 1. Block diagram of indoor WSN environment monitoring system

A. Sensor Node

It has a micro controller for processing and relaying the sensed parameters from the environment. Micro controller used here is Arduino Nano based on the ATmega328P, which has 32KB memory. It is powered through Mini-B USB connection with 5 V regulated external power supply. This sensor node interfaces sensor and transceiver antenna. This RF data modem operates at 2.4 GHz frequency in half duplex mode with automatic switching between receive and transmit mode with LED indication. The baud rate of 9600 bps is used for receive and transmit of serial data with microcontroller. This RF modem implies UART serial data transfer. The first sensor node interfaces BH1750 digital light sensor and BMP 180 pressure sensor. Each of these sensors measure light intensity and air pressure with great precession. The second node measures CO and gas, this is achieved by interfacing MQ7 CO sensor and MQ135 gas sensor. The last node, node 3, is able to sense temperature and humidity by interfacing DHT11 sensor module.

B. Sink Node

This node processes a large volume of incoming data from three sensor nodes placed in a room. Sink node combines a powerful microcontroller based on ARM Cortex M3 with a Broadcom Wi-Fi chip called photon board/P-zero, it is manufactured by Particle. This Wi-Fi chip helps to connect to cloud through internet. The node is powered through external source of 5 V DC power supply. For wireless reception of data from sensor node and transmission of the availability of particular time slot for sensor node, a 2.4 GHz frequency RF data modem is interfaced with the photon board. A 16x2 LCD display is attached to this node, it displays data received from sensor nodes. This will help to see the parameters detected if in case, system setup doesn't connect to cloud.

C. PC/Laptop

To display the end result fetched by sensor nodes and sink node we need a PC or laptop with standard specifications like Windows 10 operating system, i5 Intel processor, 8GB RAM, 320 GB hard drive and wireless 802.11g/n WPA2 support. This is the minimum specification requirement.

IV. Software

In this section, the main software parts are discussed. All this data sensed from physical environment are displayed at the cloud in the form of graphs, which is easier for us to take note and understand. Here in this system we use ThingSpeak, which is an open source internet of things (IoT) application with MATLAB analytics. It uses a HTTP protocol over the internet to fetch and store data.

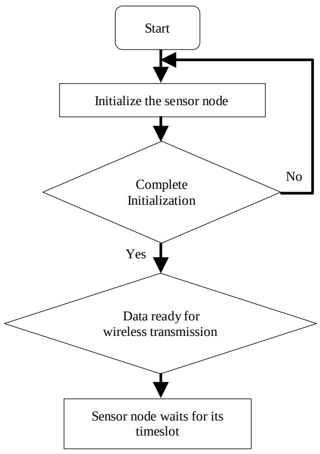


Fig. 2. Flowchart of sensor nodes

Since it being API it comes with interface where we plot the data in graphical layout. We need to define the x-axis and y-axis, channel ID and API key should match for authentication and displaying of information. The data from the sensors are feed to the sensor node microcontroller. The sensor node is responsible for processing these data. The data which are being relayed from transmitting antenna is collected at the sink node by receiving antenna. The photon board at the sink node processes all the data sent by the sensor nodes at respective time slots. Once the data are received, it than is displayed on the LCD and also at a remote PC with ThingSpeak cloud. Following flowchart gives us a proper understanding. At the sensor node the sensor is initialized. The sensors record the values as per their capacity and then it feeds these values to the microcontroller. Here the microcontroller used is Arduino Nano and it is programmed to record the sensor values. Each of these microcontroller records two sensor values. Thus, while transmitting the transmitter modem attached with microcontroller waits for its respective time slot. All signals passing over a channel is divided in to its respective time slot. Therefore, this signal doesn't interfere with other signals transmitting from other nodes.

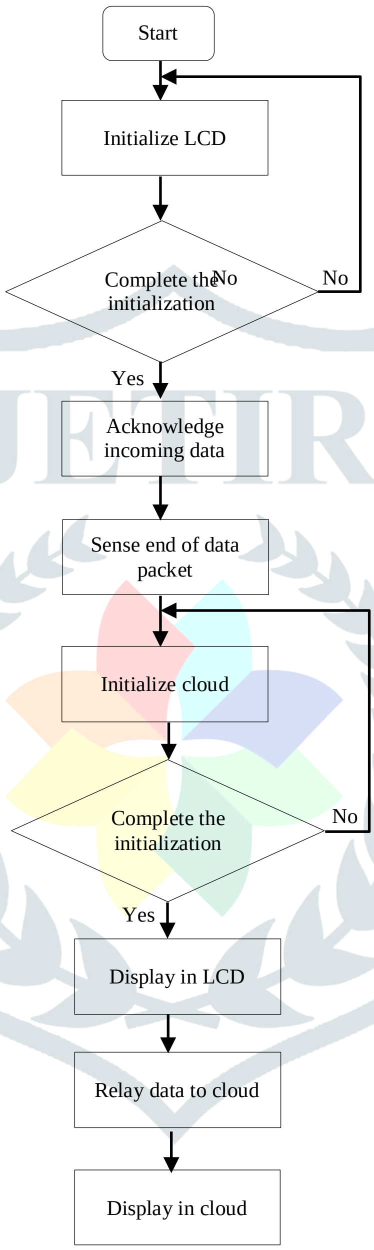


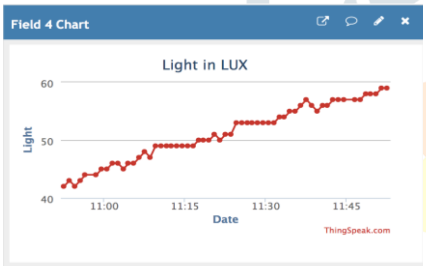
Fig. 3. Flowchart of sink node

V. Result

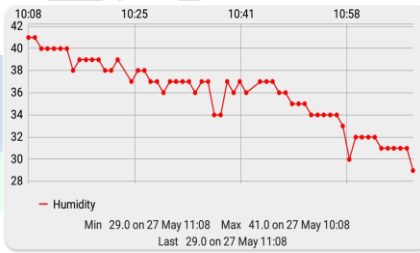
The sink node and sensor nodes were placed in a room and measurements were taken for 7 days. Measurements were taken during morning, evening and afternoon for 1 hour. Each of these sensor nodes measure two values of indoor environment. All these values were recorded and its average is shown in Figure 4. It is noticeable from this tabulation that temperature rises as the day progresses from morning to afternoon to evening, note that this data was collected during the month of May which was peak summer in Aurangabad, Maharashtra hence, temperature would rise indoor after sunset. The humidity level would drastically decrease as the day progresses to mid-day and again increase on sunset. Likewise, light intensity indoor is maximum in afternoon due to bright sunlight and open indoor windows which allows sunlight in. Light intensity indoors during morning and evening is almost similar. Air pressure indoors is maximum in morning and remains almost same in afternoon and evening. While the carbon dioxide level is maximum during afternoon and evening probably due to pollution from vehicle and nearby factories, while its minimum in morning. The pollution gas in air is also minimum in morning and gradually increases as day progresses through, which also indicates high level of traffic and also human activity is significant during this time.

Parts of the day		Temperature (deg C)	Humidity (%)	Light (LUX)	Pressure (Pa)	Carbon Monoxide (PMM)	Gas (PMM)
Day 1	Morning	34.5	35.91	15.77	94,511.94	1.54	698.67
	Afternoon	34.92	34.76	50.86	94,144.69	1.54	751.47
	Evening	35.16	35.18	16.16	94,167.7	1.55	755.47
Day 2	Morning	35.1	35.12	16.28	94,551.45	1.54	701.77
	Afternoon	36.21	33.63	51.54	94,144.81	1.55	751.66
	Evening	36.16	34.18	16.46	94,165.11	1.55	755.62
Day 3	Morning	34.67	35.88	15.12	94,513.29	1.53	698.49
	Afternoon	35.43	34.27	50.1	94,143.61	1.54	751.51
	Evening	35.56	36.26	16.78	94,166.9	1.54	754.86
Day 4	Morning	34.53	35.3	15.72	94,511.63	1.54	699.78
	Afternoon	34.93	34.19	50.31	94,145.64	1.55	751.5
	Evening	36.39	34.18	16.96	94,165.11	1.55	751.67
Day 5	Morning	35.24	33.79	16.32	94,511.93	1.54	648.62
	Afternoon	36.42	34.22	51.73	94,144.56	1.55	754.31
	Evening	36.15	35.17	16.11	94,167.78	1.54	755.48
Day 6	Morning	34.41	35.46	15.18	94,511.9	1.54	697.77
	Afternoon	35.24	34.65	51.88	94,154.69	1.54	751.57
	Evening	35.13	35.33	16.16	94,167.74	1.55	754.87
Day 7	Morning	34.47	35.86	15.57	94,510.84	1.54	697.94
	Afternoon	35.08	34.87	50.41	94,144.79	1.55	752.1
	Evening	35.48	35.3	16.23	94,167.17	1.55	755.41

Fig. 4. Table of average values



(a)



(b)

Fig. 5. ThingSpeak interfaces (a) PC (b) Smart phone

The above two figure shows the ThingSpeak cloud interfaces in laptop/computer and smartphone. For smartphone there is ThingView app of ThingSpeak. The line graph of ThingSpeak interface help in better understanding and it also enhances the monitoring capability. In graph time is plotted on x-axis and value is plotted in y-axis. ThingSpeak also provides to export all the recorded data for necessary tabulation and study purpose, which makes this cloud platform a useful tool in IoT projects.

VI. Conclusion

In this paper we designed a low-cost wireless sensor network system using three sensor nodes, a sink node, 2.4 GHz RF transceiver antenna, cloud and some open source software. The sensor node has Arduino Nano, Particle Photon board is used in sink node, both of these nodes interface RF transceiver antennas and ThingSpeak cloud helps display data to remote devices like PC. Comparing to other systems this system is low-cost, easy to maintain, easily scalable and deployable and very compact. This system uses Particle Photon board which has inbuilt Wi-Fi chip, any cloud platform could be connected with it through the internet thus making it versatile to use in many application scenarios. This photon board also come with an open source OS. Further, in this system any number of sensor nodes may be added to increase the scope of its application. This sort of system is helpful and useful in monitoring environment and collecting data. Unlike the wired system mostly used today, this system using wireless communications is efficient and robust for any sort of applications scenario. Monitoring and understanding of indoor environment are made simple by line graph of ThingSpeak cloud also ThingView app for smartphone. This system with many sensors interfaced monitors all the indoor environment parameters so, it’s a complete package which, helps the occupants to live and work better and efficiently.

VII. Acknowledgment

I would like to express my gratitude to guide Mrs. V. M. Kulkarni, Associate Professor, Department of Electronics and Telecommunication Engineering, Marathwada Institute of Technology, Aurangabad for rendering me full support and guidance, which indeed encouraged me to accomplish my work with great zeal.

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