

Ambient Monitoring using WSN for Indoor Spaces

Rama Gaikwad¹, Anil Lohar,² Jitendra Musale,³ Sneha Ramteke⁴

Assistant Professor,

^{1,2,3,4} Anantrao Pawar College of Engineering and Research, Pune, India

Article Info

Page Number: 587-592

Publication Issue:

Vol. 70 No. 1 (2022)

Abstract

This paper describes implementation of a compact self-charging and reliable ambient monitoring system using existing micro controllers and sensors for the sake of power saving, cost reduction and live monitoring. The proposed system monitors ambient light intensity, humidity, temperature, carbon dioxide level and absolute pressure of indoor spaces and provides feedback to control use of light and reduce energy consumption of air conditioners and other comfort making electronic devices. It uses any preferred wireless communication media and most power efficient and low cost Thread protocol for remotely controlling and gathering sensed data. This covers some of the drawbacks and future implementation of existing papers.

Keywords: - IoT; Wireless Sensors Network; Thread Protocol; Beagle Bone Black; ArduinoDuemilanove (Atmega 328).

Article History

Article Received: 02 January 2022

Revised: 10 February 2022

Accepted: 25 March 2022

Publication: 15 April 2022

1.0 Introduction

There are many ambient monitoring systems developed and existing from last decade, but they are more specific to their application, no ambient monitoring system is generalized neither it is commercially available for customized applications. Air quality monitoring is the major part of ambient monitoring and plays a vital role in maintaining comfort, health and nature friendly environment in the industrial infrastructure. According to the United States Environmental Protection Agency, the Department of (AQS) Air Quality System defines six different kinds of common air pollutants, namely, carbon monoxide, nitrogen oxides, ground level ozone, lead, sulfur oxides and particulate matter.[] These are the major so called criteria pollutants and thus are required to be tracked on, to ensure the quality of air we breathe.

The major issues arising from such unhealthy air are categorized under 'Sick Building Syndrome'.[] These include a set of symptoms like headaches, dizziness, and stress in concentration. The suggested system is a step towards solving such problems by providing necessary data samples for analysis and decision making.

2.0 Hardware Architecture

General Overview

The designed sensor node is a combination of an ArduinoDuemilanove microcontroller and respective sensors. This device captures various sensor values and transmits them to an IP address as and when required. The defined IP-address is preset in the Arduino's code and is

destined for the cluster head mainly the Beagle Bone Black or the gateway interface device. The Beagle Bone Black which acts as an gateway cum router will collect the sensor node's transmitted data store them on the local SAN storage or global cloud storage. All this logic is implemented in the Beagle Bone Black as a Python program and is initiated at the time of setup.

Internal Structure

The central control unit is represented by an open source Programmable System on Chip micro-controller, the ArduinoDuemilanove board. This initiates the main functioning and operation of the ambient sensors. The system can be categorized into the four major functional blocks: (1)The Input/Sensing Unit, (2)The CPU and Storage Unit, (3)The Communication Unit and (4)The Backbone Power Supply Unit.

The Input/Sensing Unit: This block consists of the sensors like temperature, humidity, light, Cozir™ CO2 Ambient Sensor, and a barometer which provide input for the system. These five senses are analogous to human sensing organs. These were chosen as their popularity, availability in local electronic stores, cost and most probably their accuracy and precision. This makes the system more feasible and survive with the other competitive counterparts. The CPU and Storage is the core micro-controller. On other hand the Communication Unit is implemented using Bluetooth module HC-05 and Ethernet shield for some nodes. As shown in the Figure. , the system has a 2-way Power Supply of a battery and a Photo Voltaic Cell shown in Figure. . The overall integration makes the system to sense different parameters simultaneously.

The ArduinoDuemilanove (PSoC)

The Programmable System on Chip, used as an acronym PSoC, is defined here as an Arduino, an open-source prototyping platform based on easy-to-use hardware and software. Arduino boards are able to read inputs - light on a sensor, a finger on a button, or a Twitter message - and turn it into an output - activating a motor, turning on an LED, publishing something online.[] You can tell your board what to do by sending a set of instructions to the microcontroller on the board. To do so you use the Arduino programming language (based on Wiring), and the Arduino Software (IDE), based on Processing. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery. Arduino has been used in thousands of different projects and applications. The Arduino software is easy-to-use for beginners, yet flexible enough for advanced users. It runs on Mac, Windows, and Linux. Teachers and students use it to build low cost scientific instruments, to prove chemistry and physics principles, or to get started with programming and robotics. Designers and architects build interactive prototypes, musicians and artists use it for installations and to experiment with new musical instruments. There are many other microcontrollers and microcontroller platforms available for physical computing. Parallax Basic Stamp, Netmedia's BX-24, Phidgets, MIT's Handyboard, and many

others offer similar functionality.[] All of these tools take the messy details of microcontroller programming and wrap it up in an easy-to-use package. Arduino also simplifies the process of working with microcontrollers, but it offers some advantage for teachers, students, and interested amateurs over other systems: Inexpensive, Cross-platform, Simple, clear programming environment, Open source and extensible software, Open source and extensible hardware.[]

Beagle Bone Black (for Sink Node/Cluster Head)

We have used Beagle Bone Black as part of this WSN because of its potential to offer enough memory for overall implementation and its processing capabilities. It uses an ARM processor for computation and has an inbuilt manufactured version of Linux Debian Operating System. So it much feasible to develop and implement various protocols and configure the in an infrastructure. It also supports various connectivity options like Bluetooth, Xbee and 802.11 Wifi Ethernet. It has ability to support external extended storage by means of MicroSD card and USB storage. This helped in replacing the traditional gateways, access points and routers.

Overview of Sensors Used

The type and specifications of sensors used here is identical to the ones used in paper []. The only enhancement made in sensors is that we have replaced the Light sensor TSL2561 with a photo voltaic cell 3WK16473 and a charging circuit, in order to increase the power efficiency. The same can be found in Figure.

2-way Power Supply and Reverse Battery Protection

The proposed system was designed with a 2 -way power supply which includes a 2V, 1000mAh rechargeable Li-ion battery and a photo voltaic cell with a charging circuit. This photo voltaic cell acts both way, as a light sensor in active mode and a recharging cell in sleep mode. The photo voltaic cell has following specifications:

- 3WK16473 photo-diode
- High-Efficiency
- Reverse voltage > 1.5V
- Operating Temperature -25°C to +85°C
- Storage Temperature -25°C to +85°C

Its charging circuit has a reverse protection designed by Robosoft.

3.0 Software Implementation

The code is loaded as a firmware into the Arduino's flash memory, which was developed and cross compiled using Arduino IDE 1.0 . The code has provisions for two independent modules : The sensor interaction and calibration module, which interfaces the sensors and network. And the Communication module which configures the network related parameters, such as

protocols and server credentials like (SSID, IP-address, Authorization passwords,etc.). All this takes place via a serial interface.

The application normally works in the default mode. It wakes up at regular predefined intervals, assesses and records sensor values, and transmits them to the cluster head. And again sleeps to retain power and charge after meeting a threshold value of battery meter. In case the server or cluster head requests data during sleep cycle, the triggering from the network takes place with the help of a preamble which is continuous sequence of 1's of eight octets. This is coded in the sink node or cluster head (i.e. Beagle Bone Black).

Using Beagle Bone Black as an access point or sink node will reduce the network traffic and also solve the Thread protocol related issues discussed later in this paper. As Beagle Bone Black contains Linux Debian Operating System, it is configured with the Thread protocols beta version, along with this it also allows data aggregation, proxy server, and to cache most recently sinked sensor data to reduce sensor interaction and power consumption.

The communication takes place with the help of Thread protocol which is the newly introduced specialized protocol for Internet of Things by Google's Nest Lab.[] And has following advantages over others :

- 1) IPv6 based,
- 2) Lightweight and low latency,
- 3) Not a whole new standard,
- 4) Collection of existing IEEE and IETF standards,
- 5) Runs on existing 802.15.4 based products. []

But in spite of so many pros, the thread protocol is not feasible with some old existing networking devices. These compatibility issues are solved in the latest official release of Thread protocol which may be an add-on for the future implementations.

Real time Scenarios

As we have discussed earlier the Arduino sensor node is programmed and made to sleep and wake-up at regular time intervals. This can be a predefined schedule or a manual trigger from the network. On the hand Beagle Bone Black will act as a bridge between multiple sensor nodes so as to interface all Wi-fi, Bluetooth and X-bee mediums. The collected sink data can be analyzed, aggregated and sent to the server as per requests. The server may request data in either UDP or TCP formats.

As the concept of IoT evolved from the efforts towards environment care and monitoring, we must attain a level of maturity and standards in order to encourage use of sensors in other domains not limited to health, home and commercial applications [],[]. By satisfying the requirements for use in WSNs, namely low cost, low power consumption, multifunctionality,

small dimensions and wireless communication capabilities, the sensor presented in this paper represents a wireless sensor node [1].(Fig.).

Recently the new context aware systems have been introduced as a part of Ubiquitous and Pervasive computing which use ambient sensors for implicit Human to Computer Interaction (iHCI). This technology is used for controlling electrical loads and lighting devices by a smart system named as context aware for its intelligence and ability to sense the surrounding environment[2]. They are from an emerging field of Artificial Intelligence.

4.0 Lifetime of the Sensor Node

To estimate the lifetime of a sensor node we have to make some assumptions that there should be insufficient light to charge the battery with a photo voltaic cell and there is no variation in illuminance. At this instance the sensor node with sleep modes will operate on battery backup. The capacity of battery may be calculated as [3]

$$C = 500\text{mAh} \times 2.0\text{V} = 1000 \text{ mWh}$$

By design, in default mode, the wireless sensor node has a power consumption of $P_d = 0.020\text{mW}$. Thus, at 50% energy charge by photo voltaic cell, the lifetime is given by

5.0 Conclusion

The correct operation of the system is guaranteed if the power source delivers at least 500mA at 2 V, but it can of course work with higher values, thus allowing high flexibility in the choice of the energy source. The depleting speeds of battery energy of sensor nodes and use of 2-way power will significantly affect the network lifetime of a WSN. This approach can not only relieve the burden of the access points, but can also integrate the energy-aware routing to enhance the performance of the prolonging network lifetime for ambient monitoring sensors. The future implementations can be a smart machine learning algorithm for mining frequent patterns as well as allow fault and intrusion detection by finding unusual behavior of sensor nodes. Making the system context aware can also be future work and is under development. By estimating the cost and accuracy of occupancy sensors we have developed a power efficient sensor cluster of ambient monitoring.

6.0 Acknowledgement

We would like to express our sincere gratitude Mr. Atul Marathe (Adjunct Professor), Dr. Ashok Saraf (Innovation Club Member) for their invaluable guidance and support throughout the research process. We also wish to thank Dr. Sunil B. Thakare (Principal, APCOER, Pune) for their support. Finally, we are grateful to all of the research participants who generously gave their time and effort to this project..

7.0 References

- [1] Silviu C. Folea, Member, IEEE, and George Mois, Member, IEEE “A Low-Power Wireless Sensor for Online Ambient Monitoring” IEEE SENSORS JOURNAL, VOL. 15, NO. 2, FEBRUARY 2015.

- [2] Ashish Pandharipande and Shuai Li, "Light-Harvesting Wireless Sensors for Indoor Lighting Control," IEEE SENSORS JOURNAL, VOL. 13, NO. 12, DECEMBER 2013.
- [3] "The Six Common Air Pollutants," <http://www.epa.gov/air/urbanair/>
- [4] "Criteria from Pollutants Survey," <http://www.epa.gov/airquality/montring.html#criteria>
- [5] "Clean Air Act,"
- [6] <http://www.epa.gov/air/caa/>
- [7] Talukdar, V., Dhabliya, D., Kumar, B., Talukdar, S. B., Ahamad, S., & Gupta, A. (2022). Suspicious Activity Detection and Classification in IoT Environment Using Machine Learning Approach. 2022 Seventh International Conference on Parallel, Distributed and Grid Computing (PDGC), 531–535. IEEE.
- [8] S. Folea, G. Mois, L. Miclea, and D. Ursutiu, "Battery lifetime testing using LabVIEW," in Proc. 9th Int. Conf. Remote Eng. Virtual Instrum. (REV), Jul. 2012, pp. 1–6.
- [9] Mihai Hulea, George Mois, Silviu Folea, Liviu Miclea, "Wi-Sensors: a Low Power Wi-Fi Solution for Temperature and Humidity Measurement," 978-1-4799-0224-8/13/\$31.00 ©2013 IEEE.
- [10] "Arduino Introduction, Setup and Specification," <https://www.arduino.cc/en/Guide/Introduction>.
- [11] "Beagle Bone Black Development," <http://beagleboard.org/BLACK>.
- [12] "Thread Protocol Implementation," threadgroup.org/Technology.aspx
- [13] D. Larios, J. Barbancho, G. Rodríguez, J. Sevillano, F. Molina, and C. León, "Energy efficient wireless sensor network communications based on computational intelligent data fusion for environmental monitoring," IET Commun., vol. 6, no. 14, pp. 2189–2197, Sep. 2012.
- [14] Gupta, S. K., Lanke, G. R., Pareek, M., Mittal, M., Dhabliya, D., Venkatesh, T., & Chakraborty, S. (2022). Anomaly Detection in Very Large Scale System using Big Data. 2022 International Conference on Knowledge Engineering and Communication Systems (ICKES), 1–6. IEEE.
- [15] J. Ko, C. Lu, M. B. Srivastava, J. A. Stankovic, A. Terzis, and M. Welsh, "Wireless sensor networks for healthcare," Proc. IEEE, vol. 98, no. 11, pp. 1947–1960, Nov. 2010.
- [16] C. H. See, K. V. Horoshenkov, R. A. Abd-Alhameed, Y. F. Hu, and S. Tait, "A low power wireless sensor network for gully pot monitoring in urban catchments," IEEE Sensors J., vol. 12, no. 5, pp. 1545–1553, May 2012. Dhabliya, D. (2022). Audit of Apache Spark Engineering in Data Science and Examination of Its Functioning Component and Restrictions and Advantages. INTERNATIONAL JOURNAL OF MANAGEMENT AND ENGINEERING RESEARCH, 2(1), 01–04.
- [17] Ariefianto, T., Purwanto, Y., Wiratama, H. "Storage Area Network based-on Internet Small Computer Standard Interface optimization using Internet Protocol Multipathing," IEEE, ISBN: 978-1-4673-4990-1 pp. 303 – 307, March 2013
- [18] Srinivas Devarakonda, Parveen Sevusu, Hongzhang Liu, Ruilin Liu, Liviu Iftode, Badri Nath, "Real-time Air Quality Monitoring Through Mobile Sensing in Metropolitan Areas," UrbComp'13, August 11–14, 2013, Chicago, Illinois, USA. Rabanal, N., & Dhabliya, D. (2022). Designing Architecture of Embedded System Design using HDL Method. Acta Energetica, (02), 52–58.
- [19] Tate, John. (dkk).2006. "Introduction of Storage Area Network." (4th Ed). USA: New York. IBM Corp.