An effective smart real-time environment monitoring system using IoT and cloud computing with the mobile application support

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Abstract. IoT and cloud computing are important aspect of innovation in today's world. The two elements are interrelated. The data is collected using the IoT systems and it is analysed and evaluated using cloud computing. Cloud enables storage of sensor data, which is used in the IoT system, analysis of this huge data, and also security of this data. One of the widely researched IoT system is real-time environment monitoring. In this paper, implementation details and results are provided of a real-time environment monitoring system for temperature and humidity air monitoring components. These data are useful for several reasons like smart power grids, server room air monitoring, equipment management etc. Sensors like DHT11 is connected to NodeMCU board to collect data and cloud services like ThingSpeak is used for data storage and data analysis. Security for the data is provided using AES algorithm. The results are shown using a mobile application which accesses the data from ThingSpeak.

Keywords: IoT · Cloud Computing · ThingSpeak.

1 Introduction

In recent times, real-time environment monitoring has become significant for many applications and for maintenance of certain devices at a particular environmental conditions. In relation to this temperature and humidity are 2 important constraints on such systems and hence monitoring of these in particular becomes significant. Such monitoring is used in devices such as heating, ventilation, air conditioning systems,in equipment management to maintain the devices at particular environmental conditions etc. On the other hand, these data are also used in weather stations and smart power grids[7] for predicting weather and generating renewable energy, respectively.

Technology has helped a lot to ease the complexity of monitoring the environment in real-time. One such technology is cloud. Cloud Computing is playing a major role in relation to IoT systems. It is an easy and convenient way to store data, access the data remotely and even analyse the data. Cloud resources

consists of servers and storage that can be quickly released with no or less management and service provider interaction[1].

$src : https : //thingspeak.com/pages/learn_more$

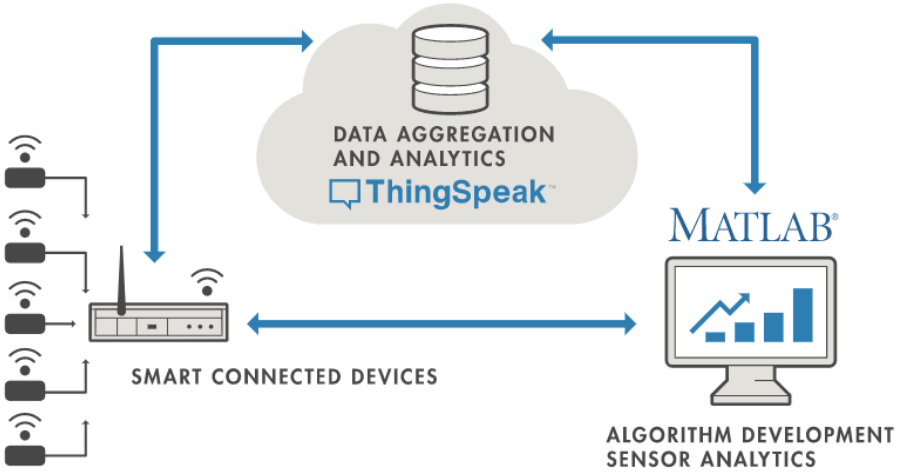

Fig. 1. IoT solution using cloud.

Here, for practical implementations, we have used IoT devices i.e. nodemcu and dht11 sensor and ThingSpeak cloud services for storage, security and analysis purposes. ThingSpeak is an IoT analytic cloud platform service for live stream aggregation, visualisation and analysis in the cloud. ThingSpeak can be interconnected to any user interface for easier access of data and data visualisation.The implementation of IoT solutions using ThingSpeak is depicted in Fig1.

This paper consists of details of practical implementation of IoT solution for detection of temperature and humidity using ThingSpeak. Furthermore, we will be discussing the related work, proposed system, implementations and results. Final section will consist of concluding remarks.

1.1 Motivation and Contribution

Real-time environment monitoring systems are beneficial in industry applications where environmental constraints like temperature and humidity has a significant impact on product quality and its lifespan. The real problem of these environmental constraints arrives during shipping and warehousing. With the current situation of the pandemic and the need to keep the vaccine at a certain temperature, the monitoring of the temperature is very essential. The implementation of the project is applicable in:

- Humidity and Temperature monitoring Laboratories.
- Food Safety.
- Warehouse and Inventory Management.
- Shipping vehicle temperature during the transport of goods.
- Special equipment management where certain devices must be in certain environmental conditions.
- Accessible from remote locations.
- An effective real-time environment monitoring system for collecting real-time data from sensors and notify the same using mobile application through ThingSpeak cloud platform.
- AES encryption and decryption security technique for data security.
- In-depth analysis of the collected data along with false alarm notification to the user.

2 Related Work

Some related works are as follows :

In paper[3], the authors have put forward their research on smart grids using cloud computing technology for security, storage and faster computations with a design idea on how to achieve such systems. The idea is a cloud computing intelligent data device which has cloud service, security, data integrity check and high storage. The main focus is the data collected using the device.

In paper[14], the authors have held testing of the developed temperature and humidity monitoring system at various locations of their college campus to monitor plant growth and cope with the agricultural changes. Here the monitoring system was developed at a low cost of Rs.1625. The developed system showed a percent variation of 0 to 8 percent for temperature and 0 to 5.97 percent for humidity. Also accuracy for the same was measured.

In paper[18], the authors proposed a system to monitor the 2 parameters i.e. temperature and humidity for server rooms. It is an IoT system which is capable of providing details regarding the changing temperature and humidity continuously. The system is connected to cloud and data is sent whenever temperature is read. The usage of telegram application sends notifies users.

In paper[17], the authors aimed at cost reduction of a system used to measure temperature and humidity. The proposed idea is the use of Microsoft azure as cloud service for storage, computations and security. It gives implementation details for 1 server room of connecting server room to sensors which in turn is connected to other hardware and to the cloud. The authentication of users are done and data can be read using web or mobile application

In paper[6], the authors have discussed about how the change in the climatic condition affects the spread of corona virus. It was observed that in extreme

temperature, the spread was minimal. This was supported with statistics and its analysis.

In paper[16], the authors researched on the increasing complexity of power meter, which is made of many sensors, and its service requirements of security, reliability and efficiency. It briefs about the usage of trustworthy cloud i.e. (Tclouds) to reduce hardware issues and improved protection.

In paper[15], the authors have made a system which monitors soil status, was prominently for data collection and monitoring the system to increase the soil quality. The data is collected in the form of tables and stored in the cloud.

In paper[9], the author implemented a real-time environmental monitoring method to achieve optimal efficiency and accuracy of collecting real-time data of temperature, humidity and moisture of soil. A mobile app was developed with farmers as the end users to help them in increasing yield by providing the correct environmental conditions information.

In paper[7],the authors explained about the assimilation of the future technology called Smart grid. The main requirement of smart grid is an efficient and robust hardware i.e. resources and storage. The technology used is cloud computing to integrate resources and provide storage.

In paper[2], the author says that the countries in the Tropical regions reflected very less death percentage. In the same way the recovery rate is high in the countries of Tropical regions ranging from 88 percent to 99 percent.It is observed that the death rate in the Subtropical countries is relatively high when compared to the Tropical regions. It can be predicted that the low temperature has facilitated the survival and the spread of Covid-19 in the Subtropical region when compared to that of the Tropical region.

2.1 Summary of the Literature

Refer to the Table 1. for the the literature survey.

3 Proposed System

The proposed system is an IoT device, real-time environment monitoring system primarily focusing on temperature and humidity constraints. The system setup is connected to ThingSpeak cloud and in turn the cloud is connected to the user interface. The IoT device consists of sensors which will collect data and send it to the ThingSpeak cloud for storage in real-time. This real-time data sent to ThingSpeak is then read by the mobile app created using MIT-App inventor[5].

Table 1. Literature Survey - Summary

Author & year	**Contribution**	**Merits**	**Remarks & future Directions**
Kasham Jummai Shamang, Abbas Said El Nafaty, 2020 [4].	The system mentioned here sends notification about the temperature on a telegram app.	easy and user friendly.	More efficient applications with better systems/hardware.
RN Sonawane, Ghule AS, AP Bowlekar, AH Zakane - 2019[14]	Achieved monitoring and control of a green house environment using sensor.	For better agricultural output.	Help in making better agricultural produce.
Paulo Macenes, Renata Travassos Da Rosa Moreira Bastos, Antonio Carlos and David Normando - 2020[6].	Temperature and humidity are not alone enough for spread of covid-19. Population density, immunity, migration patterns etc matter to.	Weather conditions and health policies are valued knowledge.	A system should be developed to take in account all the parameters and evaluate with respect to all the attributes.
Nirav Rathod - 2020[9]	IOT based Agriculture stick which helps in providing accurate data of environmental constraints.	Application in the farming. Aids farmers in maximising the yield.	Increase the number of sensors for more data and greater efficiency.
Shashank Shetty, Sanket Salvi - 2020[11]	Remote monitoring of garbage level using cloud. it separated waste based on its type. Web and mobile application for user interaction.	Less expensive and remotely accessible.	Addition of more sensors and an automatic truck can be designed which works automatically.
Patricia Morreal, Feng Qi - 2010 [8]	Distributed sensors have been used to detect environmental condition changes like volcano with respect to place and time and is notified to users.	Less costly and parameters can be customised easily.	A better user interface and provide alert scripts instead of mails for notifying users.
Sudha Senthilkumar, Brinda Krishnamurthy, Charanya R, Abhishek Kumar -2019 [10].	A patient monitoring system, which takes in details about temperature, heartbeat, humidity and body positioning.	Capable of adopting into any new changes and avoids further modifications. The results provided good performance and accuracy.	Quick alerting of the user when health deteriorates.
Pawan Singh-2018[12]	Detailed discussion on the new and different kinds of IoT technology in the field of healthcare and data monitoring of the same.	reduced medical expenses, time and human error. Early and quick detection, improved management of drug usage.	Improve healthcare system's and overcome barriers, challenges and issues.
Tinu Anand Singh, Chandra Jayaraman - 2018[13].	solution to make low power consumption MQTT protocol greenhouse adaptation.	Don't have to consider changes to the network during attachment time.	Monitor data in a larger Agricultural areas.

Fig.3. shows the architecture of the proposed system. It consists of 4 main modules. The first module is DHT11 sensor, which is a temperature and humidity sensor. The sensor is connected to the second module i.e. the NodeMCU. NodeMCU has inbuilt WiFi module which is connected to next module. The NodeMCU has a flash memory where AES encryption takes place which is a security technique. The encryption takes place in flash memory and decryption takes place when the data reaches the WiFi module i.e. to ThingSpeak. Detailed explanation of AES working is given further in the section. The mobile application then reads the data from ThingSpeak and displays for the user's view.

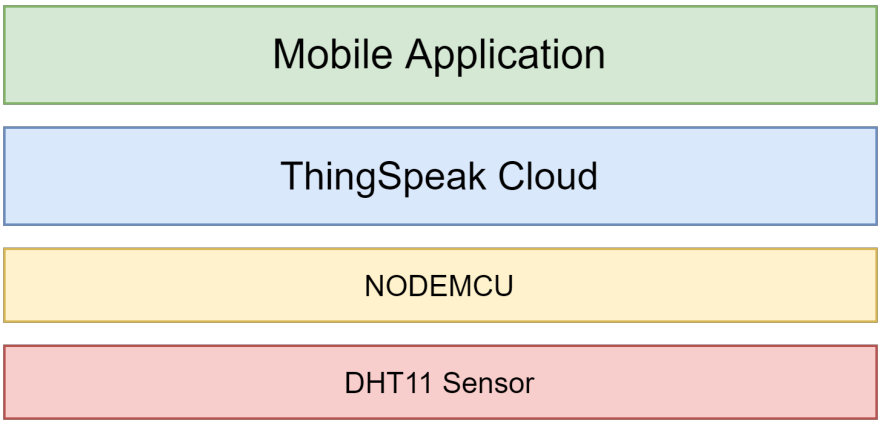

Fig. 2. Architecture

The Security of the data is provided in the flash memory of the device using Advanced Encryption Standard (AES) algorithm. AES algorithm is symmetrical cipher block algorithm. Here, aes128 has been used which means that it can convert data into 128 bits cipher blocks.

Algorithm:
*Step*1: Byte substitution
There are predefined substitution boxes which are rules for the block text bytes.
*Step*2: Row shift
Exclude the first row and shift every other row by one. *Step*3: Column mixing the cipher data is jumbled by mixing the columns.
*Step*4:Addition of round key
XOR of data with the key.

AES is proposed in various modes. Here, we have used AES Cipher Block Chaining (CBC) which uses the following formula where (1) is for encryption, where E_K represents the block encryption using the symmetrical key, and C_{i-1} is the cipher for B_{i-1}. (2) is for decryption where D_K is the block description using symmetrical key k.

$$C_i = E_K(B_i) \oplus (C_{i-1}) \tag{1}$$

$$B_i = D_K(C_i) \oplus (C_{i-1}) \tag{2}$$

4 Experimental Setup and results

The setup architecture is shown in Fig.2.

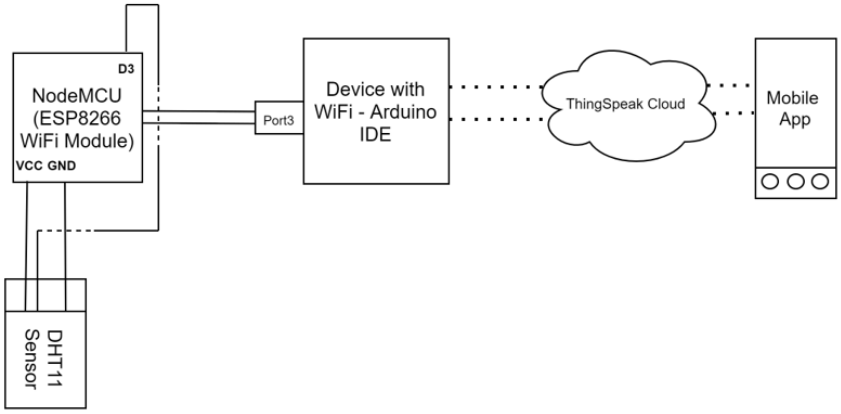

Fig. 3. Implementation

Hardware:
The major components are NodeMCU (see Fig.4) and DHT11 sensor(see Fig.5.). The V_{cc} and GND of DHT11 is connected to the V_{cc} and GND of NodeMCU respectively. The data of DHT11 is connected to D3 of NodeMCU (See Table.2. for components).The USB cable is connected from NodeMCU to the COM port-3 of the system with WiFi connectivity. NodeMCU consists of WiFi module ESP8266 which is used to connect the hardware to the ThingSpeak cloud using WiFi.(See Fig.3.) The hardware is programmed in Arduino IDE. The board used is NodeMCU-ESP.(See Fig.6,7)

Fig.6. gives a detailed circuit connections.

The header files like AES.h, DHT.h, ESP8266WiFi.h and ThingSpeak.h needs to be installed and included. The ssid and password of the WiFi must

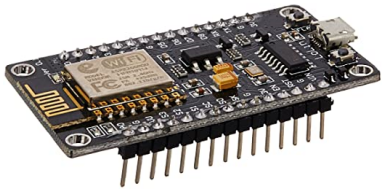

Fig. 4. NodeMCU

Fig. 5. DHT11 Sensor

Table 2. Component requirements

Components	Quantity
NodeMCU	1
DHT11 Sensor	1
Male-Male jumper wires	3
Micro USB cable	1

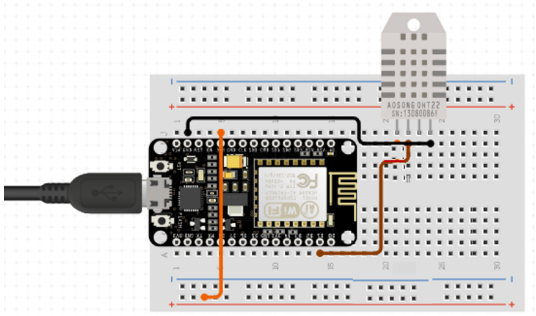

Fig. 6. Circuit

be specified. ESP8266 module should be programmed in the setup function for accessing the WiFi connectivity. The sensor should read the temperature and humidity values, encrypt the data and decrypt it as soon as the data reaches the cloud in the loop function. ThingSpeak is connected using the Write API key and channel ID.

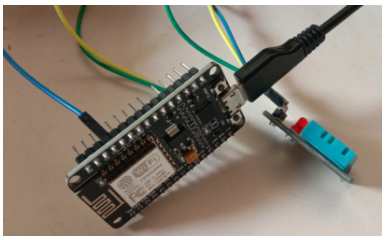

Fig. 7. Experimental Setup

ThingSpeak and Mobile Application:
The sensor's data is stored in the ThingSpeak database. Two data is collected in in every iteration: Temperature in Celsius and Humidity in %. The data is stored in the public channel of ThingSpeak for everyone to view the data in daily basis. The data can be retrieved in .CSV, .XML and .JSON formats. The data can be accessed altogether or just the recent data or just temperature data and so on. The write API key allows the hardware to store the data and the read API key allows the user interface (Mobile App) to read the data (See Fig.3.). Using the widgets we can see the real-time data for checking the correctness of the sensor reading. Different graphs can be plotted for analysis and visualisation purposes.
The ThingSpeak is then connected to the mobile app. The mobile app is made using MIT App inventor. The code uses the channel ID and Read API key of ThingSpeak to read the data and show the graphs etc. The app provides information about the app and its uses and displays the graph analysis of the temperature and humidity data.(See Fig.8.)

Result:
The final implementation of the setup leads to hardware connecting to ThingSpeak cloud and in turn it is connected to mobile app. In total 641 temperature and humidity data has been collected over a period of a week. Sample of the result is shown in Table.3. The table consists of 4 fields, namely created_at, entry_id, field1 and field2. The field 'created_at' gives the date and time in Indian Standard Time, 'entry_id' is the id given to every value stored in the cloud. field1 represents the temperature value in degree Celsius and field2 is the humidity value in percentage.

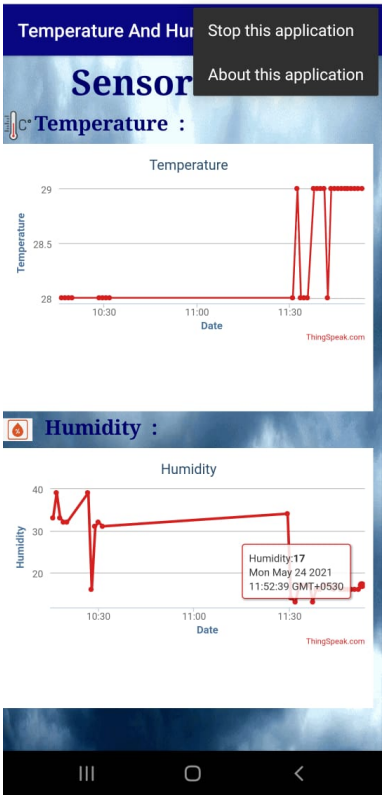

Fig. 8. Mobile application

Table 3. Sample Results

created_at	entry_id	field1	field2
2021-05-06 07:09:05 UTC	1	-	75
2021-05-06 07:09:38 UTC	2	32	-
2021-05-06 07:10:10 UTC	3	-	72
2021-05-06 07:10:42 UTC	4	31	-
2021-05-06 07:11:14 UTC	5	-	72
2021-05-06 07:11:46 UTC	6	32	-
2021-05-06 07:12:18 UTC	7	-	73
2021-05-06 07:12:50 UTC	8	30	-
2021-05-06 07:13:22 UTC	9	-	72
2021-05-06 07:13:54 UTC	10	32	-
2021-05-08 09:49:22 UTC	11	-	38
2021-05-08 09:49:55 UTC	12	30	-
2021-05-08 09:50:30 UTC	13	-	39
2021-05-08 09:51:03 UTC	14	30	-
2021-05-08 09:51:35 UTC	15	-	41
2021-05-08 09:52:09 UTC	16	30	-
2021-05-08 09:52:41 UTC	17	-	40
2021-05-08 09:53:13 UTC	18	30	-
2021-05-08 09:53:45 UTC	19	-	41
2021-05-08 09:54:18 UTC	20	30	-
2021-05-08 09:54:49 UTC	21	-	40
2021-05-08 09:55:23 UTC	22	31	-
2021-05-08 09:55:54 UTC	23	-	39
2021-05-08 09:56:26 UTC	24	30	-
2021-05-08 09:56:58 UTC	25	-	39

5 Conclusion and future work

Real-time environment monitoring IoT system is an important IoT solution for various fields of power industry, heating, air conditioning, smart power grids etc. based applications. We have considered temperature and humidity as parameters for the implementation. Cloud computing is an important aspect for the above applications in terms of storage, security, integrity and access the data anywhere. We have done a practical implementation of storing the real-time environmental constraints' data with security using 1 sensor. If we were to use millions of such IoT systems together which is connected to the cloud then there would be greater improvements and innovations in the field of renewable energy production, smart power grid, environmental monitoring, equipment management etc. These innovations would be beneficial economically and environmentally.

In the future works, the system can be upgraded to a web based application using GPRS technique and also using MQTT protocol for security.This will help not only help in remote place but also upgrade the system for monitoring larger area. Along with temperature and humidity, other parameters like pressure using barometric sensor, different components of air to check air quality etc. could be integrated into a single system and stored in cloud for better analysis.

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