Minimization of Latency for Internet of Things (IoT) in Remote Weather Monitoring System

Ezekwem Chigozie, Alumuna T.L, Onyia Tochukwu Cyprian, Akpo Esther
Department of Electronics and Computer Engineering
Corresponding Email Address: ezekwemchigoziethankgod@gmail.com

Abstract
This paper developed an IOT system with the aim of providing an easy and efficient way of monitoring climatic parameters like temperature and humidity using the Thingspeak platform. It is a relatively low cost with low power consuming system which can be deployed in various environment and remotely monitor these parameters at different time and from any part of the world if made public. The data collected was therefore analysed and visualized with the average humidity and temperature calculated. This paper was able to develop a model for estimating the delay pattern for the system. In developing the delay model for time of received packet this work adopted the least square regression method in developing the model. This model was later translated by substituting the values of the dependent variable and the independent variable with interval between the time of data transmitted t_s and time the data was received t_d. The latency result which is the interval between the time of data transmitted t_s and time the data was received t_d was $0.5377658274260\ seconds$.

Keywords: Latency, IoT, Thingspeak

I: Introduction

Imagine a world where billions of objects can sense, communicate and share information, all interconnected over public or private Internet Protocol (IP) networks. These interconnected objects have data regularly collected, analysed and used to initiate action, providing a wealth of intelligence for planning, management and decision making. This is the world of the Internet of Things (IOT). [12] Today's developments in the Wireless Sensor Networks (WSNs), Device-to-Device (D2D), Internet, Machine-to-Machine (M2M), and mobile computing technologies have a significant impact to extend the sensory capabilities of IoT networks [3]. However, due to large-scale and highly-dense nature of many IoT applications, performing timely acquisition and analysis of IoT related data is crucial to support low-latency applications. Various application requirements have brought many challenges to design more efficient and reliable industrial IoT networks. The main challenges in industrial IoT networks include low latency, low per node energy consumption, reliability, and secure data transmissions to the application servers [5]. Out of these, IoT network latency has been considered as one of the most critical issues in industrial automation and control sub-systems. The main network parameters that affect the system delay are node density, data rate, and energy per node, processing power, routing protocol and Medium Access Control (MAC) protocol [6]. To deal with the latency issue, an IoT network must be designed to meet the real-time requirements of the aforementioned application scenarios IoT improves efficiency, accuracy, economic benefits along with reduced manpower.

II: Literature Reviews/Thingspeak Overview

Silvia Ganesan et al (2024) in their study stated the critical need for improved data collection methods is underscored to enhance the accuracy of weather forecasts and address evolving climatic conditions. In their study, they stated that climate change impacts, including shifts in weather patterns and rising temperatures, highlight the importance of effective weather monitoring for agriculture, infrastructure, and national security and the introduction of IoT-enabled smart weather stations would represent a significant advancement in weather monitoring technology.

Pan Tang et al (2024) in their study on the application of internet of things wireless communication technology in agricultural irrigation management stated that the integration of Internet-of-Things technology with traditional agricultural irrigation is a crucial factor in the advancement of traditional agricultural irrigation towards smart irrigation.

Sambandh Dhal et al (2023), Mario pons et al 2023 also in their study highlighted the potential of the convergence of networks and services in increasing the availability and speed of access to the internet, enabling a range of new and innovative applications and services.

However, the research in the remote weather monitoring still require improvement in the design and implementation to reduce latency and study delay pattern to allow quick and real time access of measured parameters to clients in various destinations.

III: Material and Method/ System Implementation

The central control unit used in the presented IoT system is the sophisticated microcontroller-based Node Mcu Esp 32s. It utilizes the Arduino Integrated Development Environment (IDE) which is an open-source software package to program the controller using a high-level programming language similar to C and C++ via serial communication connected to the PC. The controller incorporates Wi-Fi Module (CC3000) which is inbuilt and embedded on it in order to upload sensor readings from DHT11 to the opensource cloud ThingSpeak. The module is configured through AT commands and needs the appropriate sequence to be used as a client. It can also work as both client and server. It gets an uses the TCP/IP model to gets its address on being connected to Wi-Fi through which it can communicate over the Internet sensors.

This system was designed by integrating the appropriate software and hardware tools. The Vcc (+5V) on ESP 32 was connected to Vcc on the DHT11 while the data pin on the DHT11 was connected to Pin 27 on the Esp 32. Ground on the DHT11 was also connected to ground on the ESP 32. This is depicted in the figure shown in figure 2 below. Required components are Arduino MEGA, LCD, GSM Module, DHT 11, Jumper wires, Bread Board.

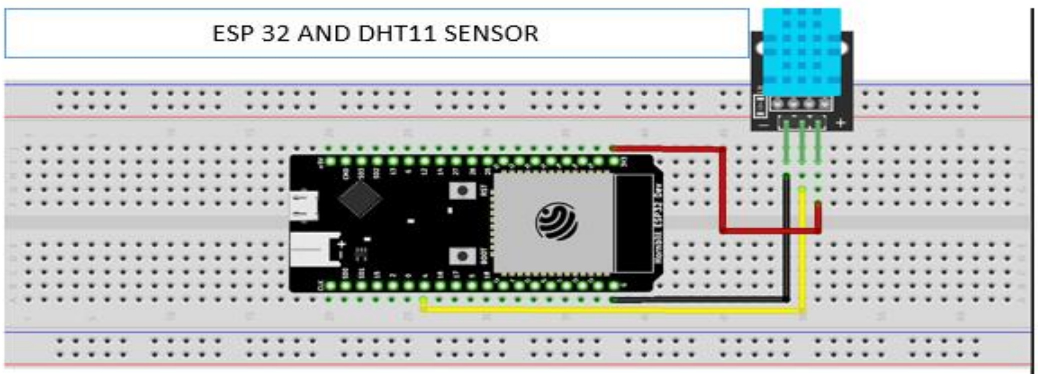

Figure 1: Bread board for DHT11 Sensor

The system is comprising of various modules that enable the implementation of this system seamless. The communication and the storage module are comprised of the controller which incorporate a Wi-Fi module on it. The Wi-Fi module on the Node Mcu Esp 32s facilitates communication and transfer of sensed values to an online IOT platform (Thingspeak API). The thingspeak which is also cloud based IoT software, allows for proper storage of data for references, analysis and visualisation. The display phase allows the measured variables or sensed data to be displayed on the IOT platform. Including the dynamic real time graph of temperature and humidity over time. The entire system was powered using a direct current supply. This was achieved by regulating the voltage to a suitable voltage of 9V and 5V respectively. The LCD, DHT11 sensor, Grove moisture sensor and the CC3000 Wi-Fi shield were powered by regulating the 12V supply to 5V using the LM7805 regulator and the Arduino board was also powered externally by regulating the 12V DC supply to 9V using the LM809 Regulator.

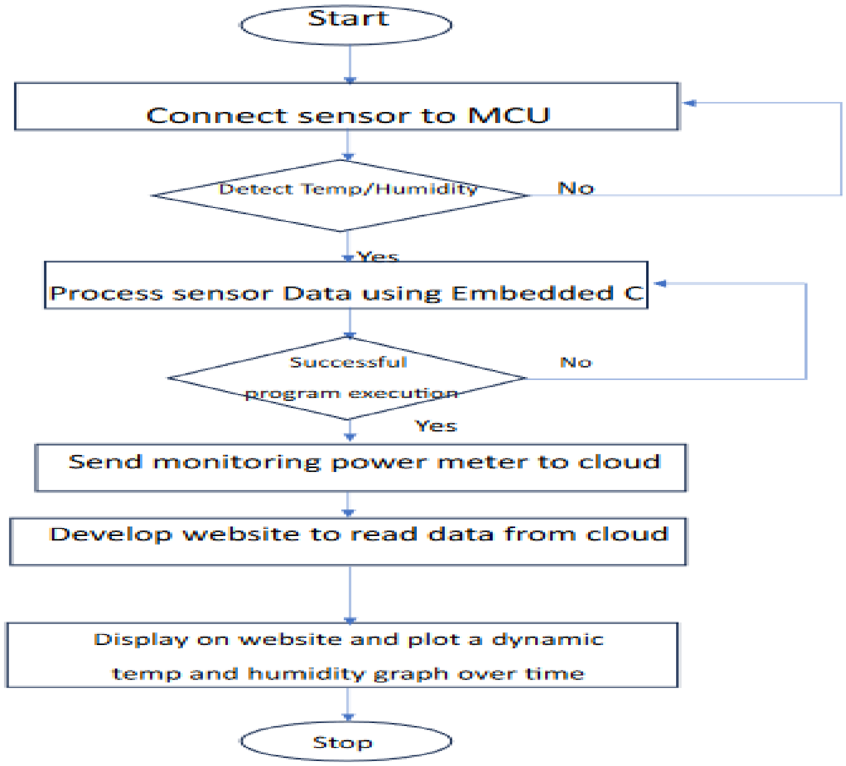

Figure 2: Flow diagram for Thingspeak IoT monitoring platform

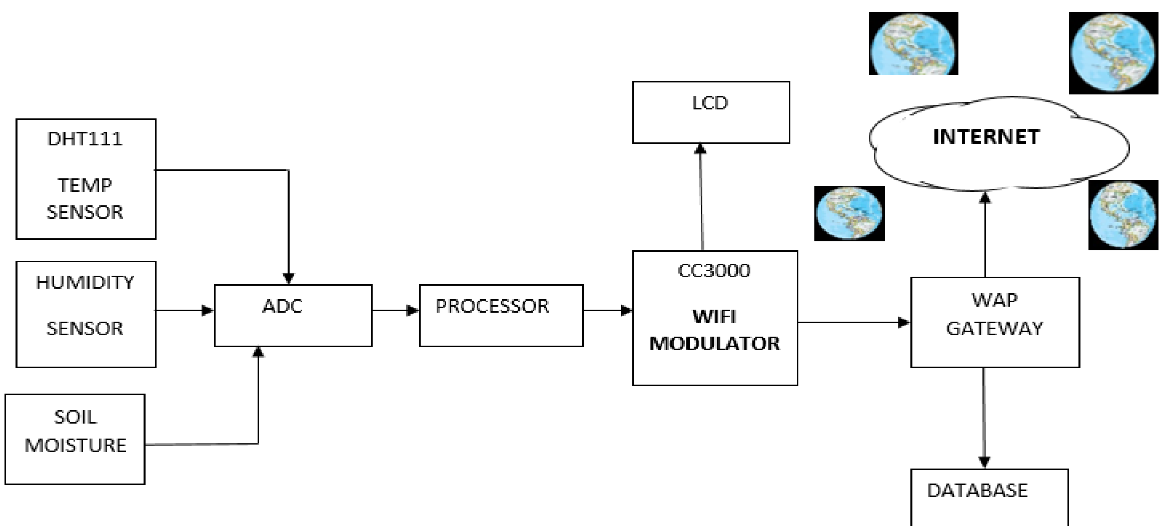

Figure 3: system model for detection of temperature and humility using thingspeak

Results

The response time and average response time for the system was calculated using equation 1 and equation 2 respectively.

$$\text{Response time} = T_R - T_S \quad (1)$$

$$\text{Average Response Time} = \frac{\sum T_R - T_S}{N} \quad (2)$$

Average response time for experiment 1 =

$\frac{2330+3140+124+3331+4030+316+4041}{7} = \frac{17312}{7} = 2473.14$ msec

Average response time for experiment 2 =

$$\frac{531+613+227+171+2146+1207+1466+2036+1715+97+438+334+194+896+1258+403+3236+188+552+117+44}{21}$$

$= \frac{17869}{21} = 850.9$ msec

Total Average for both experiments = = $\frac{2473.14+850.9}{2}$ $\frac{3324.04}{2} = 1662.02$ msec = 1.662seconds

From the result shown above the average response time for the developed system is 1.662 seconds which shows that the system is fast and good for real time applications.

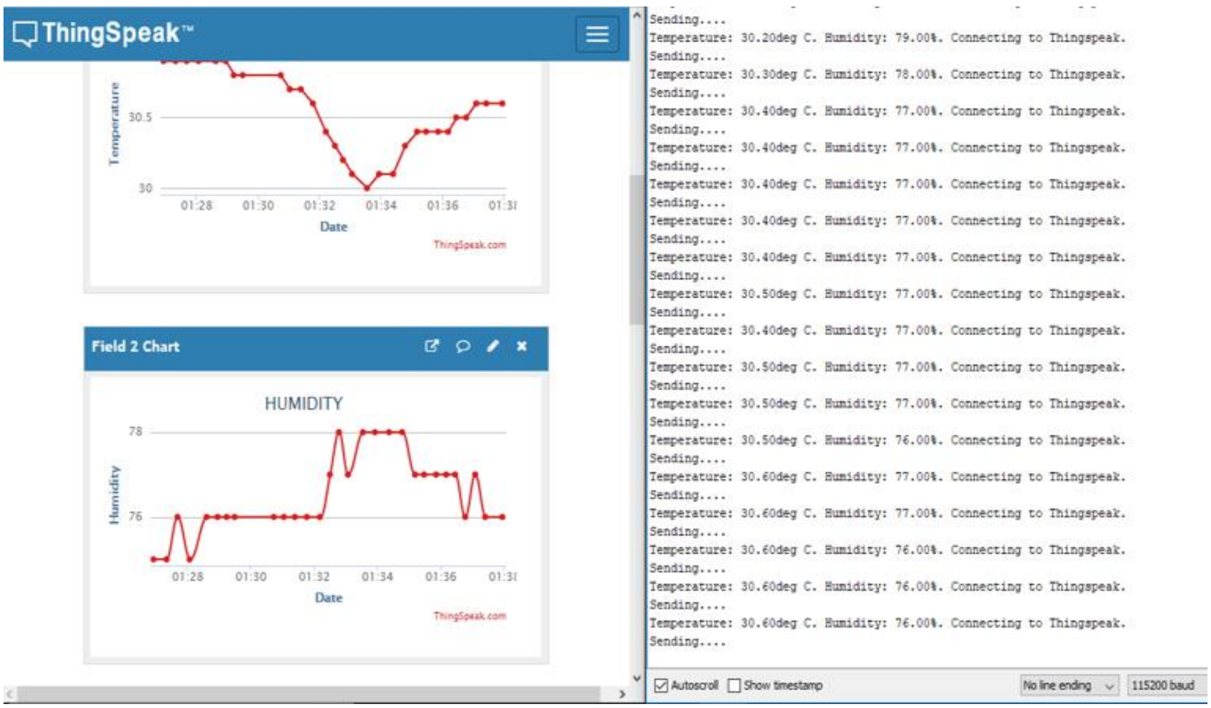

Figure 4. Dynamic Graph of Temperature and humidity Over Time On Thingspeak

Table 1: Climatic Parameter for Case 1 (**Temperature Humidity)**

Time at Source (hh:mm:ss:000)	**Temperature (ºC)**	**Humidity (%)**	**Time at ThingSpeak (hh:mm:ss:000)**	**Delay (ms)**
00:15:31:449	29.3	83.0	00:15:31:980	531
00:15:53:392	29.3	83.0	00:15:54:005	613
00:16:14:459	29.3	83.0	00:16:14:686	227
00:16:35:372	29.3	83.0	00:16:35:543	171
00:17:33:306	29.4	83.0	00:17:35:452	2146
00:17:54:199	29.6	82.0	00:17:55:406	1207
00:18:25:542	29.1	81.0	00:18:27:008	1466
00:19:09:170	30.2	80.0	00:19:11:206	2036
00:19:44:390	30.4	79.0	00:19:46:105	1715
00:20:05:904	30.4	79.0	00:20:06:001	97
00:20:26:788	30.5	78.0	00:20:27:226	438
00:20:47:895	30.6	78.0	00:20:48:229	334
00:21:08:754	30.6	78.0	00:21:08:948	194
00:21:56:269	30.9	77.0	00:21:57:165	896

00:22:17:976	30.9	77.0	00:22:19:234	1258
00:22:50:335	30.8	77.0	00:22:50:738	403
00:25:18:001	30.7	78.0	00:25:21:237	3236
00:26:20:686	30.8	78.0	00:26:20:874	188
00:27:02:848	31.1	77.0	00:27:03:400	552
00:29:11:868	31.6	76.0	00:29:11:985	117
00:28:05:944	31.5	76.0	00:28:05:988	44

Table 2. Climatic Parameter for Case 2 (**Temperature, Humidity**)

Time at Source (hh:mm:ss:000)	**Temperature (ºC)**	**Humidity (%)**	**Time at ThingSpeak (hh:mm:ss:000)**	**Delay (ms)**
01:20:31:790	29.0	84.0	01:20:32:990	1200
01:20:53:392	29.9	84.0	01:20:53:665	273
01:21:14:459	29.7	83.0	01:21:14:780	321
01:21:35:007	29.2	82.0	01:21:36:192	1185
01:22:33:150	29.3	82.0	01:22:33:470	320
01:22:54:122	30.0	82.0	01:22:55:110	988
01:23:25:008	30.0	82.0	01:23:25:542	534
01:24:10:442	30.1	82.0	01:24:10:606	164
01:24:44:745	30.1	81.0	01:24:44:857	112
01:25:05:004	30.1	81.0	01:25:05:541	537
01:25:26:334	30.2	79.0	01:25:27:887	1553
01:26:20:221	30.3	79.0	01:26:20:698	477
01:27:02:040	30.3	79.0	01:27:03:210	1170
01:29:11:407	30.4	78.0	01:29:12:235	878
01:28:05:075	30.4	78.0	01:28:05:522	447

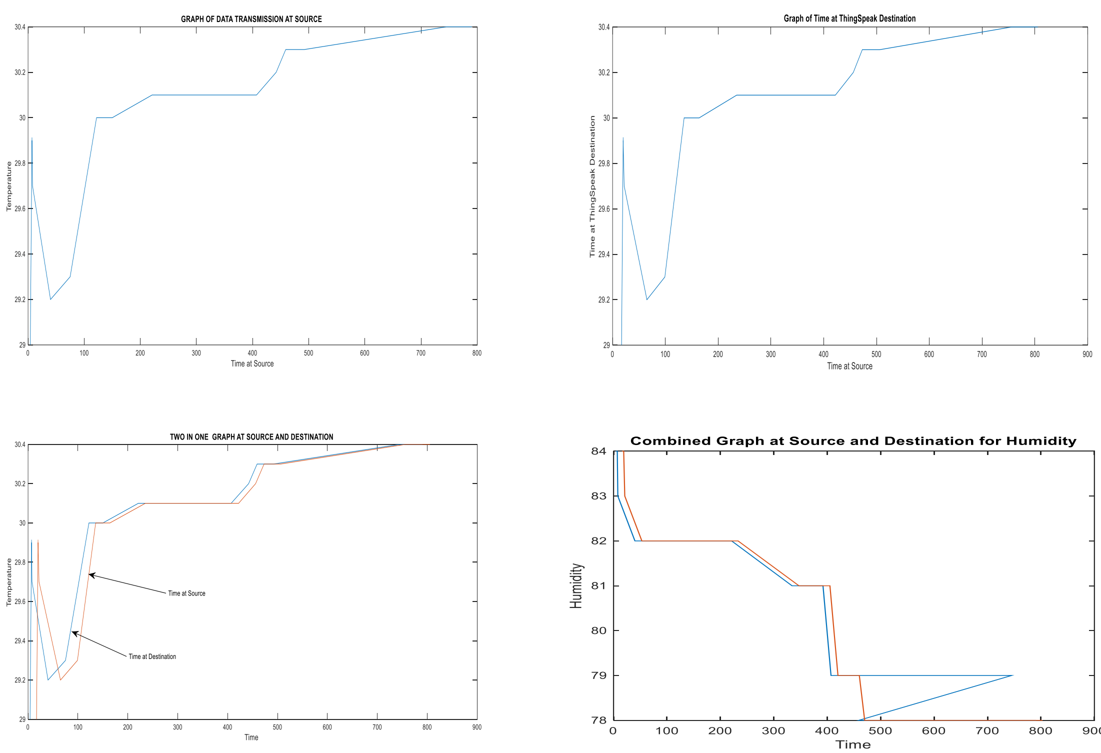

Figure 5 Combine graph of data transmitted at source and destination (temperature and Humidity)

In developing the delay model for time of received packet this work adopted the least square regression method in developing the model.
The general representation of least square regression is given as follows
$Y = a_0 + a_1 X$ ……………………………4.1

$$a_0 = \frac{(\sum Y)(\sum X^2) - (\sum X)(\sum XY)}{N\sum X^2 - (\sum X)^2}$$

$$a_1 = \frac{N(\sum XY) - (\sum X)(\sum Y)}{N\sum X^2 - (\sum X)^2}$$

Reassigning values will mean

$$B = \frac{(\sum t_d)(\sum t_s{}^2) - (\sum t_s)(\sum t_s t_d)}{N\sum t_s{}^2 - (\sum t_s)^2}$$

$$\sum t_d = 21.44121$$

$$\sum t_s = 21.23751$$

$$\sum t_s t_d = 20651152$$

$$\sum t_s{}^2) = 21.4777062$$

$$A = \frac{N(\sum t_s t_d) - (\sum t_s)(\sum t_d)}{N\sum t_s{}^2 - (\sum t_s)^2}$$

where t_d = time the data received at destination
t_s = Time data was transmitted
The model to be developed is of this format
$t_d = At_s + B$
Where

$$\sum t_d = 21.44121$$

$$\sum t_s = 21.23751$$

$$\sum t_s t_d = 20651152$$

$$\sum t_s{}^2) = 21.4777062$$

$$B = \frac{(21.44121)(21.4777062) - (21.23751)(20.651152)}{20(21.4777062) - (409.099)}$$

$\frac{11}{20.455} = 0.5377658274260$ B=0.5377658274260

$A = \frac{20(1.0325576) - (1.023)(1.1153)}{20(21.88232) - (1.046527)}$ A = 0.9538

The final model developed for the delay pattern for internet of Things from using ThingSpeak is given as follows
$t_d = 0.9538t_s + 0.5377658274260$

Conclusion

The designed IOT system provides an easy and efficient way of monitoring temperature and humidity. It is a relatively low cost with low power consumption which can be deployed in any environment and remotely monitor these parameters at different time, giving better option to access, analyse and retrieve data such as temperature and humidity from ThingSpeak database from any part of the world. This study developed a model for estimating the delay pattern for Internet of Things IoT, in developing the delay model for time of received packet this work adopted the least square regression method in developing the model. This model was later translated by substituting the values of the dependent variable and the independent variable with time of data transmitted and time the data was received.

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