



An IOT-based Antitheft System for Warehouse and Stores

¹BABARINDE, O.D., ¹ABDULLAHI H.M., ¹INNOCENT, C. ¹ONWUKWA, E.N., ¹ZUBAIR, S., ²JACK, K.E.

¹Federal University of Technology Minna, Department of Telecommunications Engineering, Minna, Nigeria.

²Federal University of Technology Minna, Department of Mechatronics Engineering, Minna, Nigeria.

*c.innocent@futminna.edu.ng

DOI: <https://doi.org/10.5455/CUJOSTECH.251009>

Research Article

Abstract

Warehouses and Stores commonly store valuable products, making them prime targets for criminal activities. Strong security measures are necessary to protect assets and maintain operational efficiency. IoT-based antitheft system involves the tracking and securing of assets in a warehouse or store. This system measures the weight of items stored in the warehouse, monitors the values in real-time, and sends them to the ThingSpeak web platform using IoT technology which also offers remote control of the system via the SinricPro platform. An antitheft alert will be triggered whenever there is a discrepancy in the stored items without authorization. This project was achieved by using an Arduino Uno Microcontroller integrated with a Load cell for weight measurements, an ESP8266 Wi-Fi Module is also incorporated for wireless communication and access to the internet. The GSM module and Buzzer serve as the alarm unit for notifying users via SMS and sound. The system demonstrated high performance in multiple areas. Weight measurement accuracy ranged from 97.02% to 99.58%, with improved precision at higher weights. The alert system responded to unauthorized access within 2 seconds, with reliable buzzer activation and SMS delivery. Wireless connectivity between the NodeMCU and cloud platforms remained stable, achieving over 98% uptime during testing. Remote switching and control via the SinricPro platform succeeded in 100% of test attempts, while the keypad-based access ensured accurate differentiation between authorized and unauthorized users. These results affirm the system's capability to enhance inventory control and security in real-world warehouse settings.

Keywords: Arduino Uno, ESP8266, Internet of things, load Cell, ThingSpeak.

Article History: Received: 17 July 2025; Accepted: 14 August 2025; Published: 29 August 2025

1. Introduction

In an era dominated by technological advancements and the seamless integration of smart solutions into our daily lives, the need for innovative security and monitoring systems has become increasingly paramount. Among the myriad applications of Internet of Things (IoT) technology, the design and construction of an IoT-based antitheft system stand out as a cutting-edge solution, particularly tailored for warehouse and store environments. Security systems are critical in safeguarding warehouses/stores against theft, unlawful entry, and other security risks. Warehouses frequently hold valuable merchandise, making them ideal targets for criminal activity. Implementing strong security measures is critical for protecting assets, maintaining operational efficiency, and ensuring employee safety [1]. Furthermore, securing and monitoring massive items in a warehouse or store will require huge manpower and manually detecting any unauthorized or suspicious movements of goods can be almost impossible.

The Internet of Things (IoT) is communication between different devices remotely using existing network infrastructures. It allows things to interact and share information without human involvement, therefore integrating the physical and digital worlds [2]. Sensors, actuators, communication networks, and data processing units are the essential components of an Internet of Things system [3]. Furthermore, IoT systems can integrate with warehouse management software, providing real-time data and analytics for better decision-making. This includes optimizing warehouse layout, identifying bottlenecks, and forecasting demand. IoT-enabled automation, such as autonomous robots and drones, can streamline picking, sorting, and transportation processes, reduce labor costs and increase productivity [4,5]. The adoption of IoT in this project permits the sharing and storing of huge data, which also enables remote item sensing and control, leading to greater efficiency, accuracy, and economic benefits [6].

Although similar research and implementation have taken place in the past, some have limitations with the devices they use and the communication technology they utilize, which restricts their functionality and drives up the cost of the applications. For instance, Harb and Iqbal [7] designed a warehouse access control system using RFID and biometric authentication, their method primarily focused on entry points and failed to address internal security concerns once access was granted. Similarly, intelligent video surveillance system, despite employing deep learning algorithms for detection and tracking, was limited by camera blind spots and the system's inability to confirm theft without definitive verification methods [8]. Gupta *et al.* [9] IoT-based systems, though effective for environmental monitoring and inventory management, had significant gaps in security implementation, notably lacking any weight monitoring or anti-theft capabilities.

The IoT-based antitheft system assists in precisely tracking the movement of goods, guaranteeing that inventory levels are always current, preventing theft or pilferage, and enabling prompt action in response to any irregularities, thereby improving overall operational efficiency.

2.0 Materials and Methods

This section covers the hardware and software concepts for an IoT-based antitheft system. It describes in detail the algorithms, flowchart, block diagram, hardware implementation, and design used to achieve the proposed system.

2.1 System Overview

The system utilizes an Arduino Uno microcontroller as the central control unit, load cells for weight measurement, a NodeMCU wireless communication module for data exchange, and a 4x4 membrane matrix keypad as user authentication mechanisms to control access. The system also encompasses the development of a webpage integrated with ThingSpeak and SinricPro cloud services for data visualization and control respectively. The system’s design is divided into two sections: hardware and software designs.

2.2 System Hardware Design

The system architecture can be seen in Figure 1 below. The system runs on a 5V, 1A power supply. The load cell, which is the major sensor, measures the weight of the item in analog format. HX711, an Analog-to-digital converter and amplifier is interfaced with the Load cell which helps us to see the Load cell data in digital format. The measured value is sent to the Arduino Uno microcontroller for processing. The Arduino uno is also interfaced with an LCD which displays the data and activity of the system in real time. Furthermore, a 4x4 keypad is also incorporated for user input and authentication. A buzzer is connected to the microcontroller for immediate theft alerts, while the GSM module is incorporated to send an SMS alert in response to any potential theft as a result of unauthorized weight variations. NodeMCU, connected to the Arduino Uno is used to send load cell data over the internet. The NodeMCU includes an ESP8266 Wi-Fi chip that transmits load cell data over the internet. We transmit load cell data using the Thingspeak cloud service. Also, with the help of NodeMCU the overall system can be switched ON/OFF from the SinricPro application. The interconnection of all the hardware components can be seen in Figure 2.

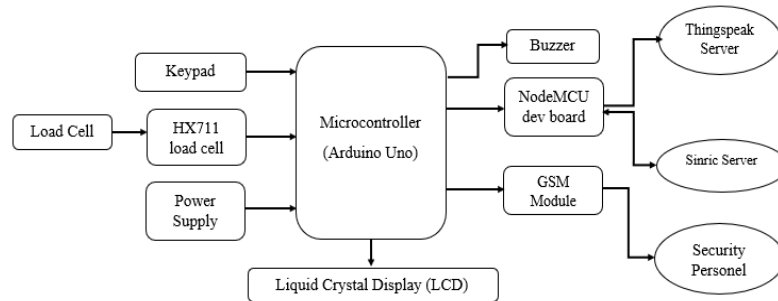


Figure 1: IOT-Based Antitheft System

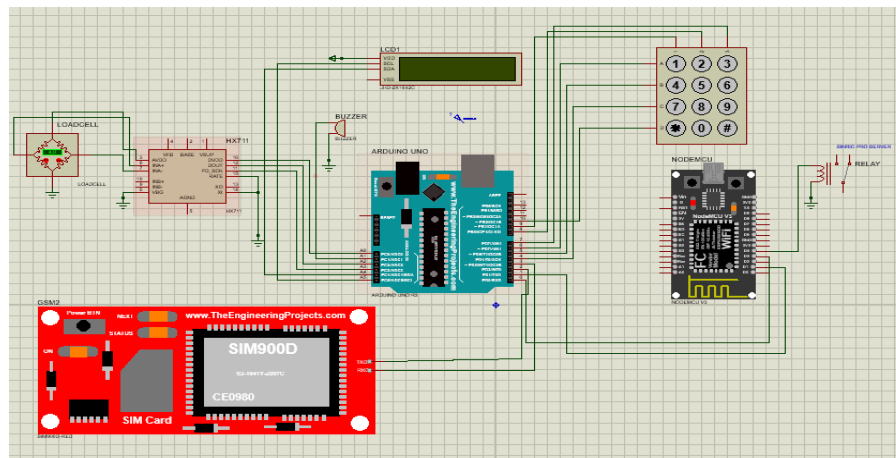


Figure 2: Schematic Diagram of the system

2.3 How the System works

When the device is turned on, the initialization process commences. The device is connected to a Wi-Fi hotspot which enables the activities of the system to be synchronized to the ThingSpeak cloud. A PIN must be registered on the system to activate the load cell to start reading. All the readings from the load cell are sent to the ThingSpeak cloud at 30-second intervals. This interval was carefully chosen to provide a balance between real-time monitoring, data accuracy, and efficient use of power and network resources. Sending data too frequently could lead to unnecessary power and bandwidth consumption, while longer intervals might delay the detection of changes in load. With a 30-second interval, the system maintains a reasonable update rate for real-time visibility, without overwhelming the network or draining power excessively. The readings of the load cell are displayed on the LCD. When the lock button is pressed, the system activates the antitheft feature. The reading at that particular time is saved in the system’s memory and displayed on the LCD. If the saved reading reduces without unlocking the system, the buzzer alarm will be triggered, and an SMS will be sent to the user.

2.4 Software Design

The software part of the work involves the Arduino IDE, the Thingspeak user interface, and the SinricPro application. The Arduino IDE was used to program the Arduino Uno and NodeMCU. The Thingspeak receives data from the hardware setup and offers visualization and analysis. A simple landing page was developed for ease of accessibility to the Thingspeak and SinricPro website.

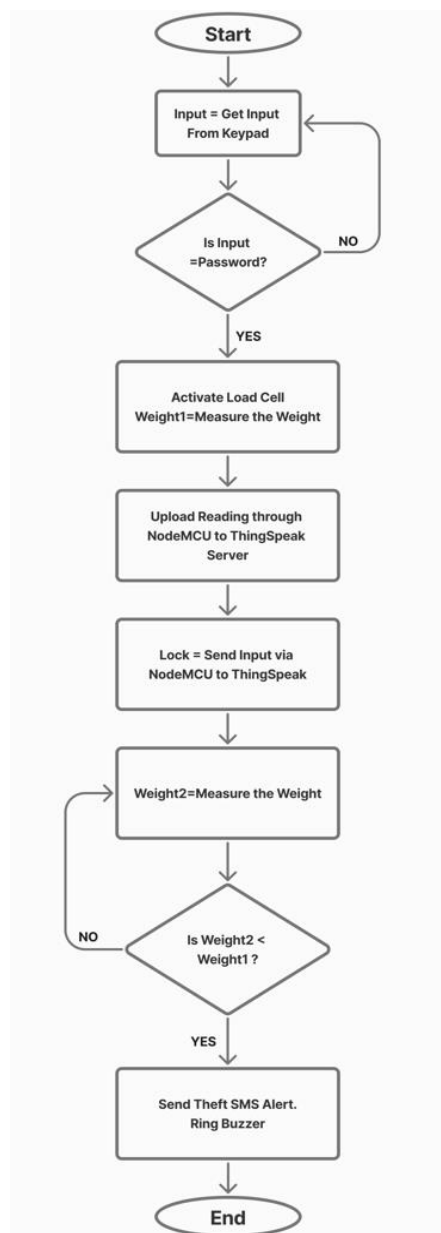


Figure 3: System Flow Chart

3.0 Results and Discussion

The system underwent comprehensive testing and evaluation across four key areas. The user verification test assessed the system's ability to distinguish between authorized and unauthorized users through PIN verification mechanisms. Weight variation testing involves placing different weights on the load cells to simulate various scenarios, such as the addition or removal of items, allowing observation of the system's response to weight changes. Network connectivity testing evaluated the reliability of wireless communication between ThingSpeak, SinricPro, and NodeMCU under different network conditions. Finally, the user interface test examined the webpage's functionality, focusing on its ability to provide detailed summaries and real-time updates while assessing overall usability for system monitoring and management purposes.

3.1 Precise Weight Measurement

To replicate a variety of scenarios, such as adding or removing items from the system, different weights were placed on the load cells. A variety of items with known weights were measured on the system. The values were displayed on the LCD as shown in Figure 4. In addition, Table 1 shows results obtained from the measurement.

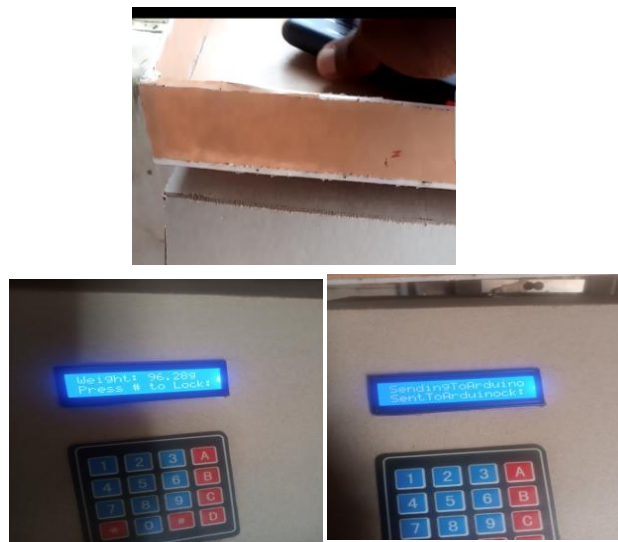


Figure 4: Measured weight

Table 1: Results obtained from different weight measurements

Entry ID	Actual Weight (Grams)	Measured Weight (Grams)	Degree of Accuracy (%)
1	100.00	96.26	97.02
2	200.00	194.32	97.19
3	450.00	439.67	97.56
4	650.00	644.32	99.08
5	946.00	946.02	99.58

This table displays the results of weight measurements comparing actual weights against measured weights and their corresponding degrees of accuracy. The data shows five different weight measurements ranging from 100 grams to 946 grams. Each entry includes an Entry ID (1-5), the Actual Weight (known standard), the Measured Weight (obtained from the measurement device), and the Degree of Accuracy expressed as a percentage. Notably, the accuracy improves as the weight increases, starting from 97.02% for 100g and reaching 99.58% for 946g, suggesting that the measurement system performs more accurately with heavier weights. This pattern indicates that the weighing system has better precision for larger masses, with all measurements showing above 97% accuracy. Figure 5 shows a brief visualization of the test.

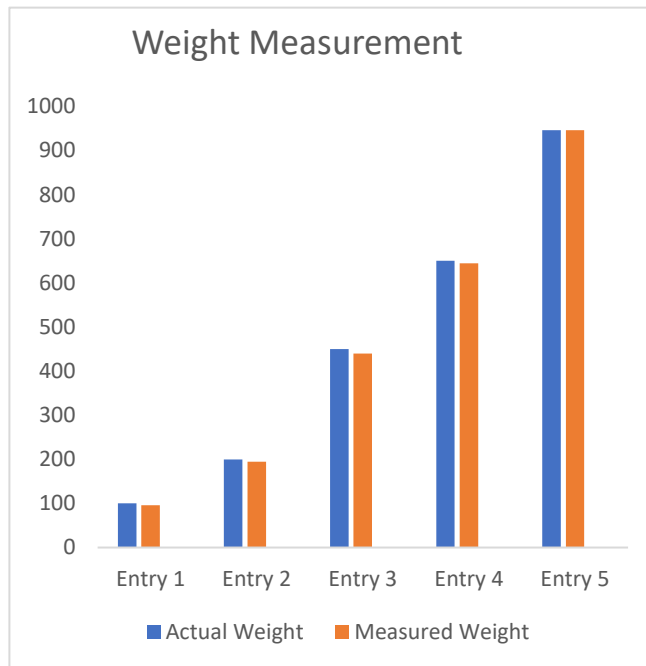


Figure 5: Visualization of the Measured weight

3.2 Software and User Interface

The landing page designed for the prototype is shown in Figure 6:

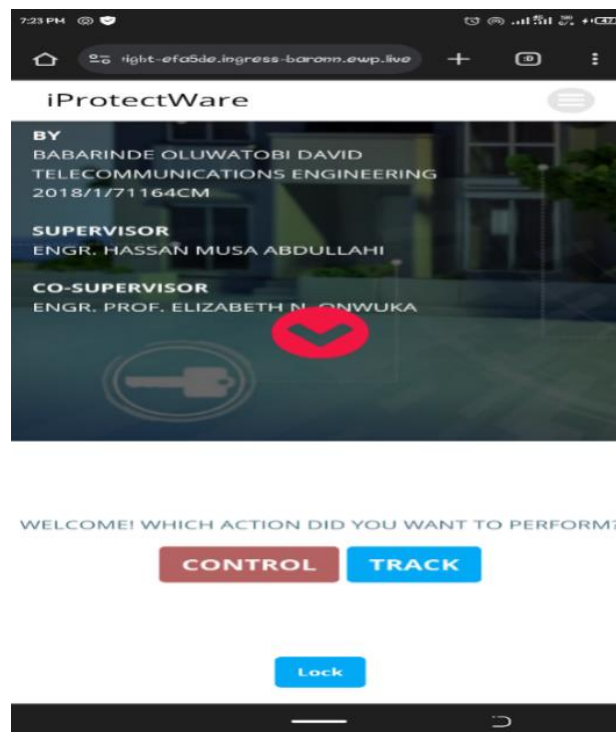


Figure 6: User Landing Page

The above landing page is designed to host the Thingspeak and the SinricPro services on a single page. The CONTROL button is linked to the SinricPro website, while the TRACK Button is linked to the Thingspeak website. The LOCK button on the landing page is to hide the two buttons mentioned above from authorized users.

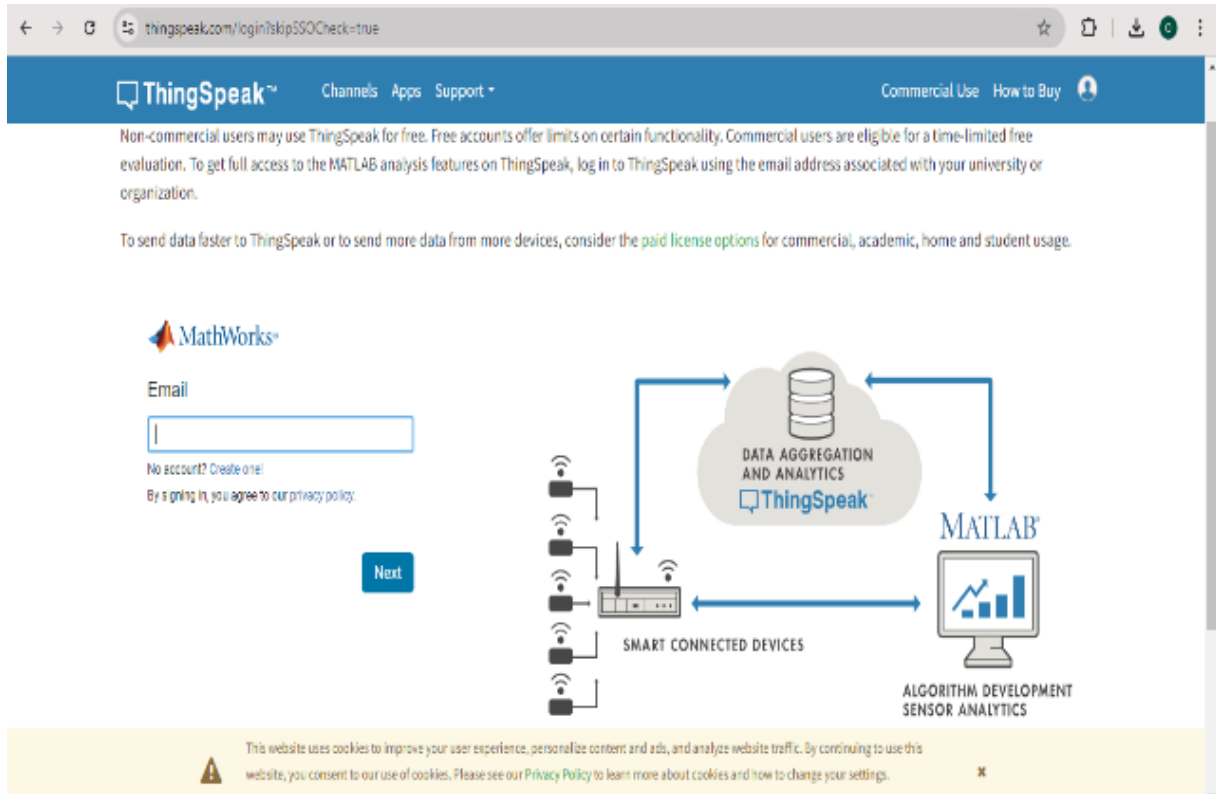


Figure 7: Thingspeak Login Page

The user login page shown in Figure 7 provides access to data received from the system. Users can log in using their registered email and password. Figure 8 shows the SinricPro interface, which provides the control functionality.

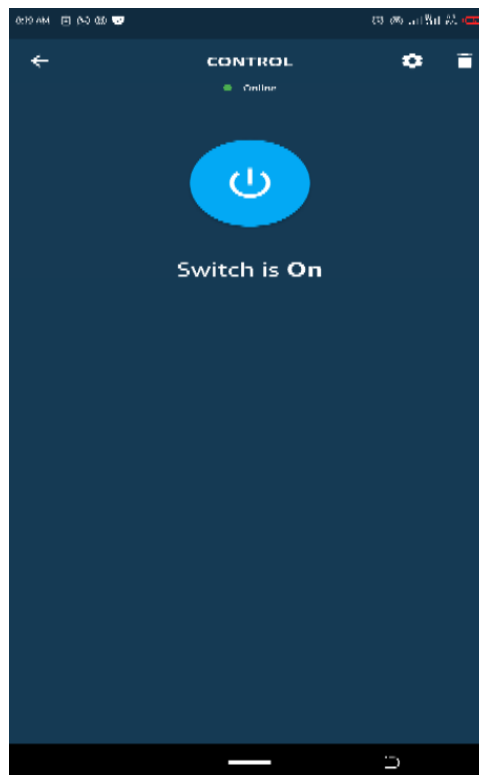


Figure 8: SinricPro Interface

3.3 Data Visualization and Monitoring

The NodeMCU's dependable data transmission to the ThingsSpeak cloud platform enabled real-time monitoring. The data received from the Arduino microcontroller are transmitted in real time to the ThingsSpeak cloud. Figure 9 shows the data field, while Figure 10 provides the visualization of the received data. The data field shows the date and time the data was received with their corresponding values.

	A	B	C
1	created_at	entry_id	field1
2	2024-05-27T19:01:12+01:00	1	0
3	2024-07-13T11:46:25+01:00	2	6.61
4	2024-07-13T12:03:43+01:00	3	-8.47
5	2024-07-26T09:31:41+01:00	4	187
6	2024-07-26T09:31:59+01:00	5	115
7	2024-07-26T09:32:17+01:00	6	89
8	2024-07-26T09:32:35+01:00	7	124
9	2024-07-26T09:32:54+01:00	8	101
10	2024-07-26T09:52:21+01:00	9	68
11	2024-07-26T09:52:39+01:00	10	162
12	2024-07-26T09:53:31+01:00	11	45
13	2024-07-26T09:53:49+01:00	12	187
14	2024-07-26T09:54:05+01:00	13	57
15	2024-07-26T09:54:23+01:00	14	196
16	2024-07-26T09:54:41+01:00	15	103
17	2024-07-26T09:55:01+01:00	16	99
18	2024-07-26T09:55:19+01:00	17	42
19	2024-07-26T09:55:36+01:00	18	50
20	2024-07-26T09:55:55+01:00	19	173
21	2024-07-26T09:56:13+01:00	20	98
22	2024-07-26T09:56:31+01:00	21	186

Figure 9: Data field from Thingspeak

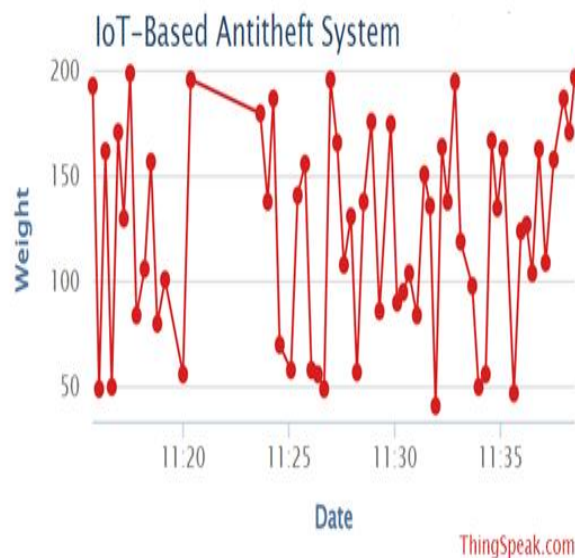


Figure 10: Data visualization of the received data

3.4 Results of the Alarm System

When an effort was made to gain unauthorized access, and when there were notable weight changes without the required authorization, the system successfully set off the buzzer alarm, and an SMS alert was sent to the user. SMS alerts are shown in Figure 12.

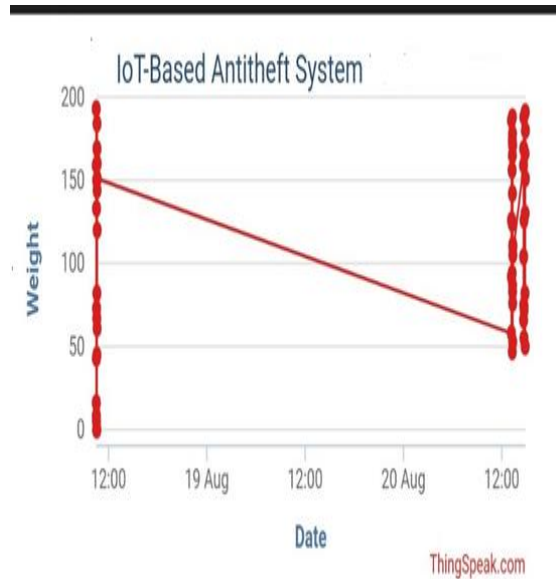


Figure 11: Data visualization on Thingspeak

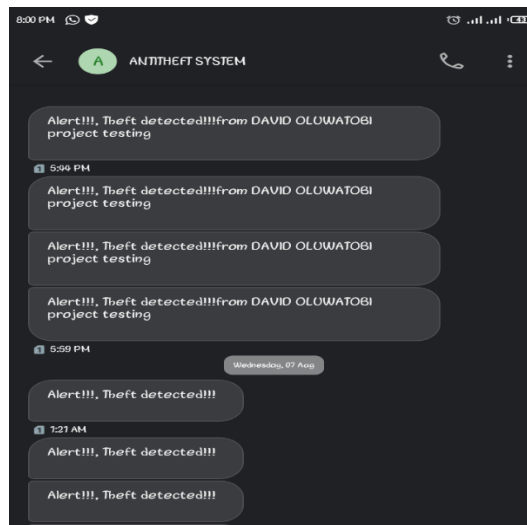


Figure 12: SMS Alert

4.0 Conclusion

The IoT-based Antitheft system has proven to be a cutting-edge approach used to reduce thefts in the warehouse environment. The development of an Internet of Things-based antitheft system has shown to be a workable way to enhance security and inventory control. The system employs wireless communication, load cells, and cloud-based data management to efficiently monitor weight variances, identify unwanted access, and furnish real-time data for analytical purposes. The system's capability of preventing theft and losses is demonstrated by its capacity to measure weight precisely and to sound an alarm in the event of illegal access. Users can effectively monitor the system and swiftly respond to incidents because of the interface's ease of use.

Although the system achieved its objectives, but a few limitations were observed with the following recommendations:

- Improve sensor integration: To offer a more complete monitoring solution, include more sensors, like motion detectors or video cameras.
- Strengthen security protocols: Boost the security of the system to guard against data breaches and illegal access. Biometric authentication may be employed
- Carry out field testing: Install the system in an actual warehouse setting to assess how well it performs in various running circumstances.

Acknowledgment

We greatly acknowledge all the lecturers in the Department of Telecommunications Engineering, Federal University of Technology Minna as well as the Head of Department of Telecommunications Engineering, and the Dean of School of Electrical Engineering and Technology, Federal University of Technology Minna.

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