Smart City Waste Management System Using Internet of Things and Cloud Computing

Chapter · January 2021

DOI: 10.1007/978-3-030-49342-4_58

Smart City Waste Management System using Internet of Things and Cloud Computing

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Abstract. Indiscriminate disposal of solid waste is a major issue in urban centers of most developing countries and it poses a serious threat to healthy living of the citizens. Access to reliable data on the state of solid waste at different locations within the city will help both the local authorities and the citizens to effectively manage the menace. In this paper, an intelligent solid waste monitoring system is developed using Internet of Things (IoT) and cloud computing technologies. The fill level of solid waste in each of the containers, which are strategically situated across the communities, is detected using ultrasonic sensors. A Wireless Fidelity (Wi-Fi) communication link is used to transmit the sensor data to an IoT cloud platform known as ThingSpeak. Depending on the fill level, the system sends appropriate notification message (in form of tweet) to alert relevant authorities and concerned citizen(s) for necessary action. Also, the fill level is monitored on ThingSpeak in real-time. The system performance shows that the proposed solution may be found useful for efficient waste management in smart and connected communities.

Keywords: solid waste, Internet of Things, cloud computing, smart and connected communities, smart city.

1 Introduction

The rate at which solid wastes are produced in most developing countries is becoming alarming. This increase may be due to recent population growth and rural-urban migration [1]. Garbage is made up of non-renewable resources used daily to meet our needs then throw away. As increase in consumption of paper, clothing, bottles, and product packaging increases, the generation of garbage also increases significantly. The form and type of solid waste depends on a number of factors which include the living standard and life style of the inhabitants of the region and the natural resources found in the region. There are two categories of Urban waste namely, organic and inorganic. The organic waste category can be further categorized into three units: non-fermentable, fermentable and putrescible [1]. The Putrescible wastes tend to decay faster, and if not cautiously managed, decomposition can lead to an offensive odour with an unpleasant view. Fermentable waste which also tends to decompose rapidly do so without the accompanying of offensive odour. Non-fermentable waste most times do not decompose or do so at a very slow rate. Unless organic waste is managed appropriately, the stricken negative effect it has will continue until full decomposition or stabilization occurs. Decomposed products which are poorly managed or uncontrolled can and often times lead to contamination of air, water and soil resources [2].

One of the challenges a developing country faces due to rapid increase in population is proper solid waste management. A typical example is the garbage bins seen around which appear overfull to the point of spilling out, leading to environmental pollution. The effect of this is increase in the number of diseases because it gives room for insects to breed. Solid waste requires systematic management the content, origin or hazard potential notwithstanding as this will ensure environmental best practices and living standard. Because solid waste management forms a very critical aspect of our environmental hygiene, it is therefore necessary to incorporate it into environmental planning [3].

The recent advances in computers have led to the birth of new innovations and opportunities like the Internet of Things where things (embedded systems) that are connected to the internet can also be controlled and interacted with via the internet. The term Internet of Things (IoTs) was first introduced by Kevin Ashton, a former director of the Auto-ID Centre of MIT in 1999 [4]. The idea of IoTs is to connect objects around us through wired and wireless network with human intervention. Communication and exchange of information are carried out by the object to provide advance intelligent service for the users.

In the case of the proposed solid waste management system, the bins are connected to the internet to relay real-time information of the status of the bin. The rapid growth in population in recent years has led to more waste disposals, necessitating the need for a proper waste management system to avoid unhygienic living conditions. Implementation of the system translates to the bin being interfaced with microcontroller-based system with ultrasonic sensors and a Wi-Fi module. The data which would be sent from the bins would be received, analysed and processed in the ThingSpeak cloud that displays the level of the garbage in the bin on a graph in its web page.

The main drive of solid waste management is the reduction and elimination of adverse effect of waste materials on human health and environment leading to improvement in quality of life. In this work, an intelligent solid waste monitoring system is developed using Internet of Things (IoT) and cloud computing technologies. This is a recent innovation as cloud computing has been applied in other areas like [5][6][7][8]. Ultrasonic sensors are employed to detect the fill level of solid waste in each of the containers. The data obtained by the sensor is then transmitted to an IoT cloud platform, called ThingSpeak, using a Wi-Fi communication link. For each designated fill level, the system sends appropriate notification message (in form of tweet) to alert relevant authorities and concerned citizen(s) for necessary action. Also, the fill level is monitored on ThingSpeak in real-time.

2 Related Works

The waste management system in [9] was developed using RFID, GIS and GPS interfaced with a low-cost camera for monitoring of solid waste [9]. The main goal of the system was to monitor the waste content of the bin using an RFID tag attached to each bin. The purpose of the tag was to monitor and track the bin while collecting the waste. The camera was attached to the truck to collect images of the bin whenever it enters the bin's area in order to take images before and after collecting the waste.

The proposed system in [10] utilized sensors and a radio frequency transmitter to embody a smart trash system. Two sensors were employed for the monitoring. The two sensors which were used are an IR proximity sensor which detects the level of the waste in the smart bin and a load sensor which senses and measures the load of the waste in the bin. When the bin is filled up to a specific load and level, it generates a signal that is sent by the RF transmitter. The local base station receives then receives the transmitted signal

In this system [11], the IR sensors which are four in number act as a level detector to show the diverse levels of the garbage in the bin. When the garbage in the bin gets to the highest level, the output of the fourth IR receiver indicates active low. The output of the sensor is sent to the microcontroller. The AT commands facilitate the messaging service sent to the control room through the GSM module. The message consists of information on garbage levels of respective bins. A GUI was developed to observe the data connected to the garbage bin for different selected locations.

In the proposed system [12], an integrated system of RFID, GPRS and geographic information system will resolve the issue of solid waste. The waste bins located are different points in the public area would provide inputs to the sensor module. The sensor is placed at the bin's maximum level. When the garbage crosses that level, the sensor relays the information to the ARM 7 controller through Zigbee wireless technology. The drawbacks of using Zigbee technology is the short range, low data speed and low complexity [13].

This paper is an extended version of a previous published work [14]. In the present work, an intelligent solid waste monitoring system is developed using Internet of Things (IoT) and cloud computing technologies. The fill level of solid waste in each of the containers, which are strategically situated across the communities, is detected using ultrasonic sensors. A Wireless Fidelity (Wi-Fi) communication link is used to transmit the sensor data to an IoT cloud platform known as ThingSpeak. Depending on the fill level, the system sends appropriate notification message (in form of tweet) to alert relevant authorities and concerned citizen(s) for necessary action. Also, the fill level is monitored on ThingSpeak in real-time.

3 Materials and Methods

Multiple waste disposal bins are located throughout the Campus and these bins were enabled with low-cost embedded device for tracing the level of garbage in bins and a unique ID for easy identification of every full bin per time in the area was provided. The connected device transmits the level as well as the unique ID whenever the set threshold limit is reached. ThingSpeak will also receive data from the system to show in real-time the level of the bins in order for the bins to be monitored anywhere from a remote location.

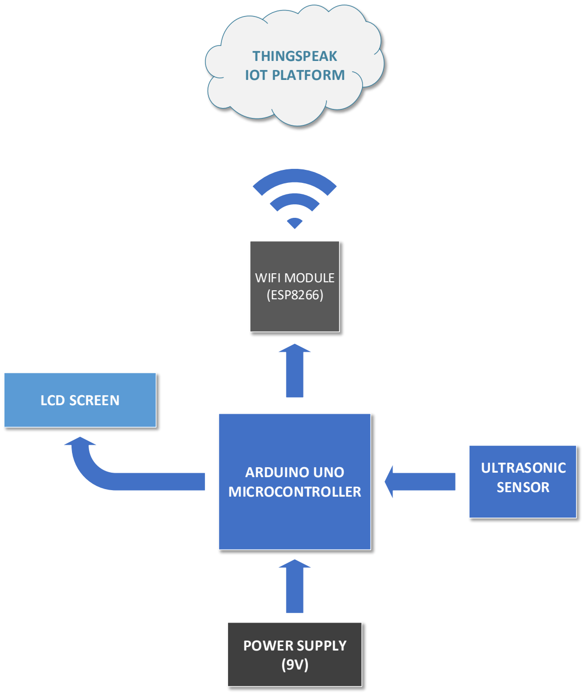

Figure 1. Block diagram of the Proposed System

The hardware unit will consist basically of the controller unit, sensor unit, display unit and the network interface unit. On the other hand, the software will essentially be made up of the microcontroller source code used to program it and ThingSpeak configurations.

For monitoring the level of the waste in the bin, the system makes use of ultrasonic sensors placed at the apex of the bin for accurate measurement of the garbage level. The measured data is compared with a pre-set level the waste shouldn't exceed. An Arduino Uno microcontroller is the component that serves as the brain of the system with all components connecting to it. The LCD receives readings from the ultrasonic sensor via the microcontroller and displays it. A Wi-Fi module connected to an access point will be used for sending data to ThingSpeak. The microcontroller communicates serially with the module to send both data and commands. The module is initially connected to ThingSpeak IP address with a write API key to enable publishing of data on the platform. It receives data from the controller, and configured in station mode, sends it over the internet to a particular ThingSpeak field that can be accessed anywhere to show in real-time the level of the bin in a visual form. The system will have a twitter account. ThingSpeak which has a feature called “ThingTweet” will be interfaced with the account to enable the system send a notification in the form of a tweet post when the level of garbage collected in the bin crosses the set limit, prompting immediate action.

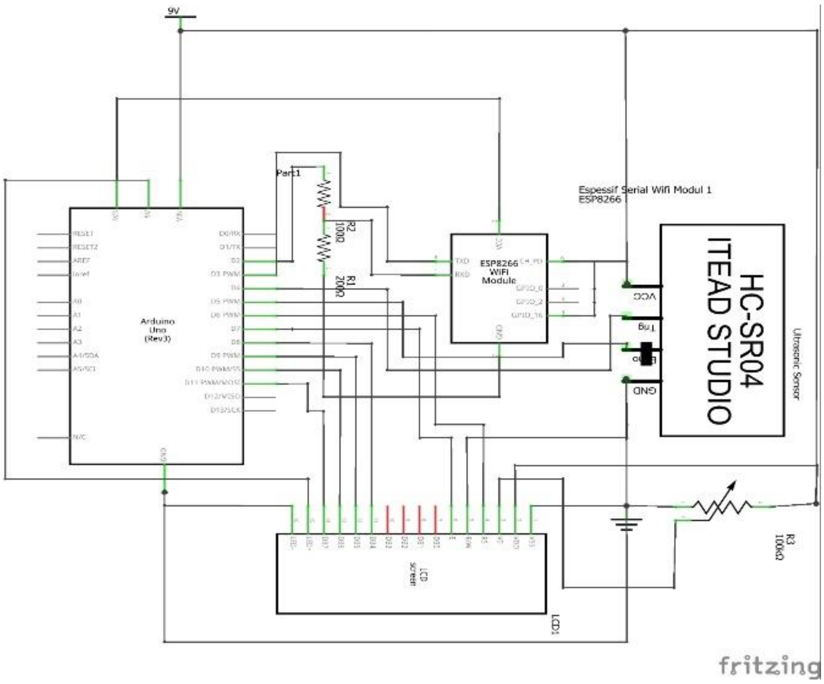

Figure 2: Schematic diagram of the smart waste monitoring system

4 Results and Discussion

This section contains details on the implementation and testing of the smart waste monitoring system. The working operation of the proposed system is explained in detail. Proper functioning of the various subunits that make up the system is of utmost importance because one fault in any part of the system would affect the total functionality of the entire system. Therefore, testing of all sub units were carried out in order to eliminate design and implementation error that could have occurred during construction.

The hardware unit consist basically of the controller unit, sensor unit, display unit and the network interface unit. On the other hand, the software is essentially made up of the microcontroller source code used to program it and ThingSpeak configurations.

Fritzing is an open source tool used for schematic and printed circuit board design and simulation. The system's design framework, circuitry and PCB layout were carried out using the Fritzing software. It was the preferred choice because of its vast library which contains all the components which the system required. Simulation was also carried out to ensure a proper working design before commencing the main development saving cost. Figure 3(a) shows the design layout of the Fritzing application containing the breadboard view of the system.

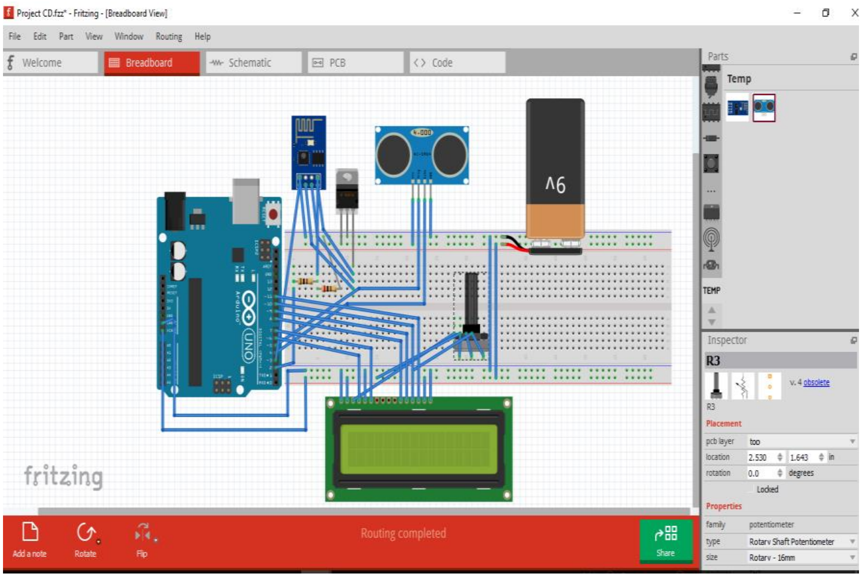

Figure 3 (a). System Design Implementation

The ultrasonic sensor is made up of four pins which are Vcc, echo, trigger and ground. For the implementation, the echo pin is connected to pin 4 and the trigger pin to pin 5 of the Arduino microcontroller. The power source, Vcc, is connected to the microcontroller's 5V output pin, and the ground (Gnd) is connected to the ground of the microcontroller. The module is powered with a 3.3V source gotten from the output pin of a regulator connected to 9V. It comprises of a total of 8 pins but only 6 are used for interfacing with the microcontroller. The module communicates serially via its transmitter (TX) pin directly connected to the receiver (RX) pin of the controller and the receiver (RX) pin connected via a voltage divider configuration to the controller's transmitter (TX). The rest of the pins which are the chip power down (CH_PD), Vcc and reset are connected to a positive supply, with ground (GND) tied to negative.

The entirety of the system was tested to ensure proper working condition and to verify that it met all required tasks it needs to carry out during its operational cycle. Data transmission delay test was also carried out to ascertain the time it takes for the system to send measured bin level to ThingSpeak to get published. The table below shows readings of the delay of each data transmission to ThingSpeak. ThingSpeak was configured to receive data from the system, publishing it in a channel. The data published is in the form of a bar graph which corresponds to the level of the bin. The channel receives update every 16 seconds, representing each as a bar. The platform, after it had been synched with the system was tested to ascertain that no error was present in the connection. When the set condition of the system is reached or exceeded, ThingSpeak sends a preset tweet notification via its tweet react app also present on its platform.

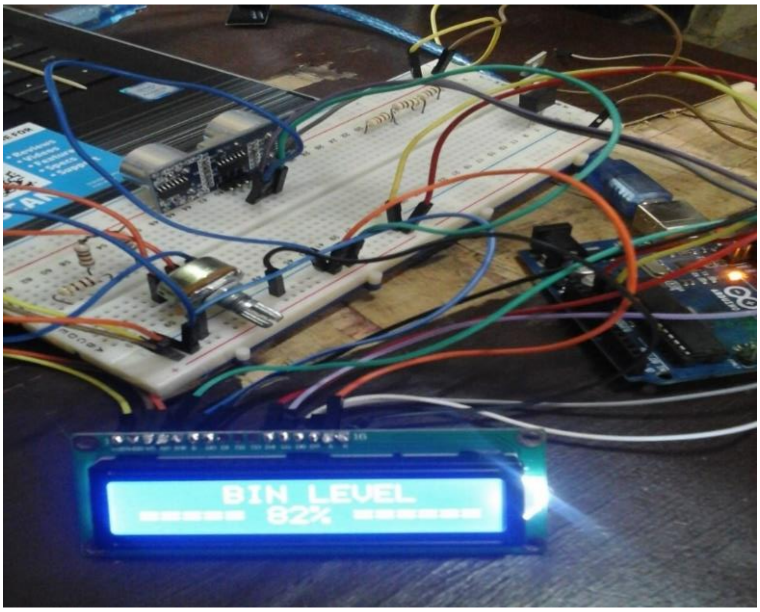

Figure 3(b): System Connections

The system is housed in a white, plastic casing which is attached to the side of a trash can. Wires that tap out from the side opening of the plastic casing run to the top of the bin, connecting to the ultrasonic sensor where it is positioned. The cover of the casing has an opening where the LCD comes through. The visual representation of data on ThingSpeak corresponded with the measured bin level. This validated the proper operation of the monitoring function of the system. The random nature of data delivery duration was attributed to network traffic and speed of internet connection. The operating performance of the level sensor was verified to operate according to desired standards, in order to facilitate system sensitivity to environmental changes. The system's remote monitoring aspect was also verified. The status of the bin can be accessed at any time, with automatic update occurring at defined intervals. The performance of the tweet react tweet alert was validated. The time it took to post a tweet was dependent on internet connectivity speed. On a slow connection, there was delay before a tweet post, but on a fast connection, post was instantaneous.

Figure 4: Implemented System

Table 1: Results of System Testing

Sent Data	**Data Delivery Duration (seconds)**
Data 1	18s
Data 2	18
Data 3	21
Data 4	18
Data 5	19
Data 5	22
Data 6	18
Data 7	20
Data 8	19.25
Average	**18**

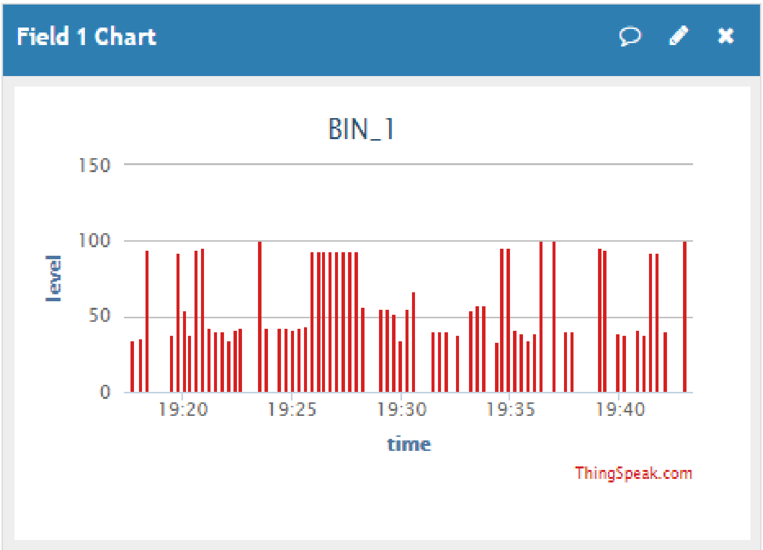

Figure 5 (a): ThingSpeak data representation in Case 1

Figure 5 (b): ThingSpeak data representation in Case 2

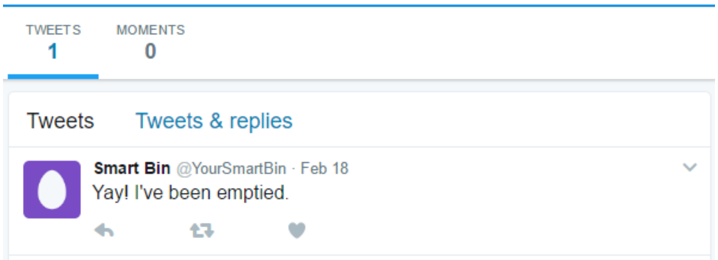

Figure 6: Tweet notification

5 Conclusion

Solid waste management is faced with a number of issues which include lack of throughput, inadequate solid waste data, efficiency problem, delays in collection and resistance to new technologies. Presently, waste management is a major problem for authorities who are responsible for such task because it's a costly service and it hugely impacts the environment as a whole. This study introduced a smart waste monitoring system that uses several sensors and communication technologies to achieve the set task. The proposed system was achieved through the development of theoretical models, layout and decision-making algorithms in the course of the project.

There is an enormous amount of room for the development of this project in order for it to meet commercial standards. One of my many recommendations would be that of the addition of other sensors e.g. accelerometer. The accelerometer will make the system save more energy by turning on the system to measure the bin level only when the lid is opened to dispose waste. The system would then update its current state on ThingSpeak and turn off, preventing unnecessary measurement when the bin's level has not been altered due to dormancy. Another recommendation is the use of solar panel for power generation making its power supply autonomous.

Acknowledgment

The authors wish to appreciate the Center for Research, Innovation, and Discovery (CU-CRID) of Covenant University, Ota, Nigeria, for partly funding of this research.

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