PROMOTING AN IoT-BASED WASTE-BIN MANAGEMENT SYSTEM IN HIGHER INSTITUTION

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Abstract
The accumulation of waste around faculty and hostels in higher institutions has become a great sense of concern to both staff and students. Often time the scene of the dumb sites is characterized by unpleasant smell and germs that can be harmful to the health status of both staff and students. To maintain the waste collection and proper waste disposal, we propose an IoT-based waste-bin management system. The IoT-based waste-bin management system employed the use of cloud server (Thingspeak) capable of computing, analysing and presenting a graphical representation of waste with the aid of an ultrasonic sensor through the microcontroller unit embedded with WiFi module. The ultrasonic sensor monitors the waste in respect to the time difference between the emitted and receipted wave of the sensor at a frequency of 40 kHz from a distance of 2 cm to 400 cm. The microcontroller samples, digitized and processed the sensor data before being sent over the network to the cloud server. The result obtained is a graphical representation of the status of the waste viewed from both the liquid crystal display (LCD) and the web interface. The graph varies from 25% to approximately 75% filled value of the waste-bin. The system can be used for proper monitoring and for future decisive actions on amount of waste generated. The device is easy to implement due to its cost-effectiveness.

Keywords: Cost-effectiveness, Cloud Server (Thingspeak), Microcontroller, Ultrasonic Sensor, Waste-bin

Introduction
The need to build and live in a clean, hygienic and unpolluted environment is a guarantee to a healthy quality of life and a sustainable environment free from infectious diseases. This can be achieved through a proper waste management system. An effective waste management system is essential to suit the current quantity and composition (Mohd *et al.*, 2017) of waste produced in our fast-growing higher institutions in Nigeria. The waste created from different sources can be timely monitored to enhance cost-effectiveness in daily operations of waste collecting trucks using the internet of things (IoT) applications. IoT is an all-encompassing application that can provide efficient and reliable solutions to waste management issues in higher institutions.

Various solutions have been provided to solve the issue of waste deposal in society (Omar *et al.*, 2016). Aside from the traditional methods which are not cost-effective and require human effort, a remote sensing solution was also in practice in Malaysia (Omar *et al.*, 2016). The use of automated vehicles location systems to monitor the timely collection of waste is another method that was implemented in (The Star, 2011). With the above-mentioned methods, none was able to optimize cost-effectiveness in their implementation and collection time of waste management.

In this paper, we propose an IoT-based waste-bin management system that would not only promote efficiency in service delivery and cost reduction but also can collect and analyze data from the sensor devices used. The computation and analysis of generated waste data will aid planning and support a decisive decision towards building an efficient waste management system. We believe there is no better place to promote an IoT-based waste-bin management system than the higher institutions due to the state of reasoning and innovation needed to upgrade existing waste infrastructures to remain among the developed country in the area of technology.

Many research works have been published in different areas of disposal of waste, based on IoT technology. For instance, the research work of Catania and Ventura (2014) suggested the collection of garbage by planning an intelligent monitoring system through a Smart-M3 platform – an extension of the cross-domain search for triple-based information. This research uses two phases; the first phase monitored and measured the levels of waste inside the container which are transmitted and stored. The second phase uses the calculated information that was collected from the measured waste to optimize the routes of waste collection. The research of Anagnostopoulos *et al.*, (2017) presented a macro view of a waste management system that involves planning and execution of waste, transportation of the waste from a specific place to another based on the type of waste and the process of recycling of the waste that can be reused. The research addresses different model of waste management infrastructure services for Smart cities based on IoT technology without dwelling on the merit of the sensors applied for monitoring and the communication methods used. The deployment of sensors to an entire city for managing and monitoring of waste collection was proposed by Sharma *et al.,* (2015). The research focuses on the analyses of the huge amount of data visualized at real-time to have an insight into the status of waste-bins around the city. The optimization of vehicle routing and the waste collection was also implemented by Lu *et al.,* (2015).

The researchers propose a multi-restricted and multi-compartmental routing problem to decide the route by modelling container scheduling strategies. The results of this study illustrate that the differentiated collection has better-searching routing strategies with low cost of collection which can drive intelligent and ecological solutions. The geospatial and IoT technologies manipulations (Fallavi *et al.,* 2017) as a pilot study for reliable smart city and Machine to Machine (M2M) waste management using Ultrasonic sensors was implemented in (Ruiz, 2016). The study was used to monitor waste management operators to ensure there is service delivery based on the terms and condition of their contract. The introduction of smart-bins with a specific identity (ID) was implemented in (Ramya & Sasikumar, 2017). The research determines who is responsible for the waste container when it is filled up by querying the database and sending a notification that contains the container ID and location using the global system for mobile communication (GSM).

The research work of (Mwangi & Mburu, 2016) employed the application of radio frequency identifier (RFID) in monitoring and managing the activities of collected waste. The study uses a cost-effective camera (Arebey *et al.,* 2010), and infra-red (IR) sensors (Medvedev *et al.*, 2015) to explore the surroundings when the dumps reach overflow. The proposed work saves cost, reduces time and human effort. The deployment of sensor nodes such as weight, level, temperature and humidity, all embedded using smart Metering v2.0 board from Libeum was proposed by (Mamun *et al.,* 2015). The author explored the advantages of wireless sensor technologies in managing waste and guarantying some level of hygiene in the society. The system comprises a microcontroller with a built-in accelerometer that read all data transmitted to the receiver from the sensor through general packet radio service (GPRS) and Zigbee communication media. The received data were stored in a database and displayed using a developed web application.

The contribution of all the reviewed work above have made the waste collection very impressive and effortless. However, the cost of implementation of most of these reviewed work might not be viable due to the implementation and maintenance of a database in their operations. Therefore, to reduce the cost of Implementation and maintenance, an IoT-based waste-bin management system was proposed. The device uses an on-line server ('Thingspeak') instead of building and hosting a database which cost certain amount. The server can compute and analyze sensor data in real-time which provide easy access to information on waste-bin management on the campus.

The rest of the paper is organized as follows; Section two has the material and method adopted and section three comprises of the results and discussion segment. Section four concludes the research work.

Material and Method

The implementation of the proposed waste-bin management system consists of 5 units, namely; the sensory unit, the processing unit with an embedded WiFi module, display unit, cloud server and power supply unit as depicted in Figure 1.

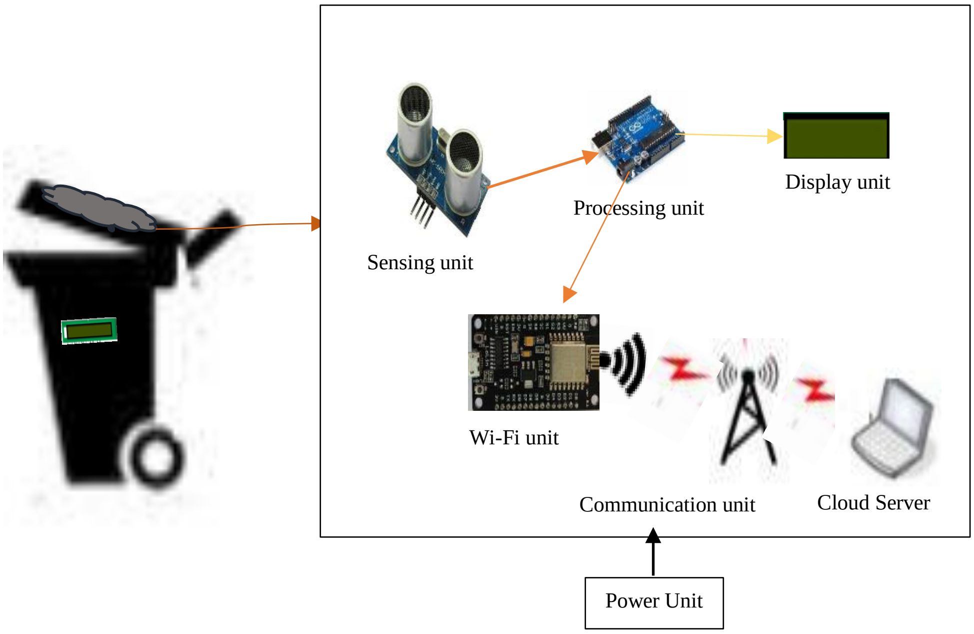

Figure 1: The Schematic Diagram of an IoT-based Waste Monitoring System

Sensory Unit

The sensory unit consists of high accuracy and stable ultrasonic sensor. The sensor emits ultrasonic waves at a frequency of 40 kHz from a distance of 2 cm to 400 cm in the air to senses any objects within the perimeter. As the wave propagates across any object, it will reflect on the sensor. The sensor has two cylindrical sections on its front (like a tiny speaker and tiny microphone) which sends and receives sound pulses. The time differences between the sending and receiving wave signals are used to determine the distance to the object.

Processing Unit

The processing unit comprises of the ESP8266 Arduino Uno microcontroller embedded with Wi-Fi module. The information from the sensory unit is sampled, digitised and processed by the microcontroller. The processed information is then sent to the Wi-Fi module for onward transmission to the cloud server (Thingspeak) for further computation and analysis. The processed information by the microcontroller is also displayed on the display unit. During the configuration of the microcontroller in C++ language, the password and the access point name together with the cloud server destination were provided. The implementation was done in Arduino IDE written in C++ language.

Display Unit
The display unit used in this research is a LCD of the 16x2 LCD as illustrated in Figure 1.

Cloud Server
The cloud server employed in this research is Thingspeak. Thingspeak is an open-source IoT-based application that allows the creation of channels using application program interface (API) read and writes key generated (Pasha, 2016) for every stored information. The information from the microcontroller can be computed, plotted graphically and analysed real-time as the waste-bin is monitored. The interface of the proposed waste-bin management system from the cloud server.

Power Supply Unit
The power supply unit provides power to the entire system. The power supply used is a USB lithium battery power pack of 500mAH that provides 5V power to the microcontroller. The microcontroller has a maximum voltage rate of 10V and a minimum rate of 3.3V. The choice of the power supply unit was due to the durability and reliability of lithium batteries.

Principle of Operation
The information from the sensory unit is received and processed by the ESP8266 microcontroller (MCU) as the ultrasonic sensor continue to monitor and measure the time difference between the emission and reception of ultrasonic waves from the waste in the waste-bin. The sensory unit is designed to trigger the MCU to display the information on the display unit of the waste-bin when the distance between the sensor and the waste in the waste-bin is becoming shorter (i.e. 25%, 50% and 75% of the waste, which are the pre-set threshold). At this moment, the cloud server (Thingspeak) also computes, analysed and plot graphically every information received from the MCU through the WiFi module. The readings on the LCD also changes as the level of the waste increases from 0.25 to 0.5 to 0.75 and then to full level respectively. This information is available to both the authority and users for necessary actions to be taken. Figure 2 and Figure 3 depicts the circuit diagram and flow chart respectively.

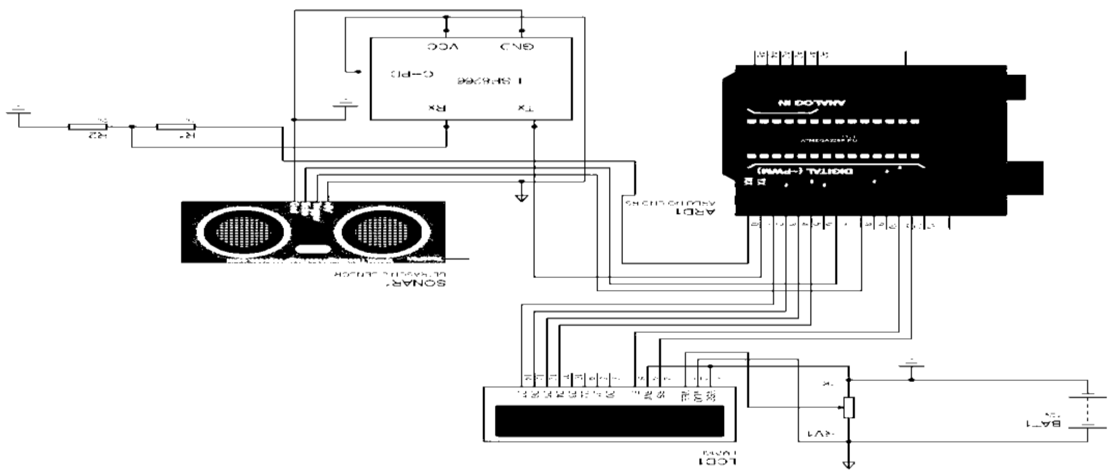

Figure 2: The circuit Diagram of an IoT-based Waste-bin Monitoring System

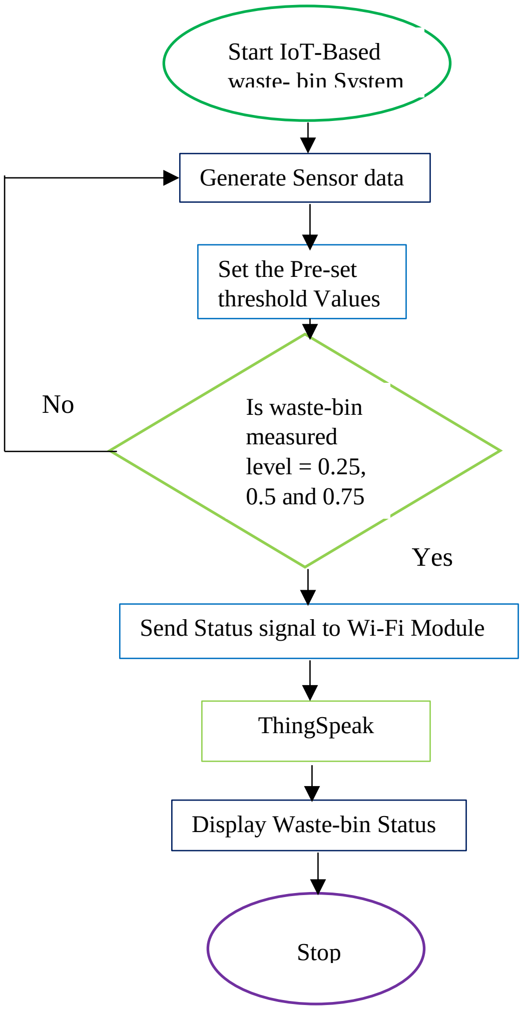

Figure 3: Flow Chart of the Implemented System

Result and Discussion

The proposed IoT-based waste-bin management is depicted in Figure 4. The result of the transmission, analysis and computation of the collated sensor data on the cloud server is graphically presented in Figure 5. It can be observed from the graph, that the plotted data were within an interval of 5s which illustrates that the sensed data were sampled, collated and transmitted in every 5s. The plot on the graph varies from 25% to approximately 75% of the waste in the waste-bin as observed on Figure 5. For efficient waste-bin management, there is a need for fast internet connectivity.

The inclusion of an LCD on the IoT-based waste-bin management system was to provide clear readings as the waste levels increases from 25% to 75% and eventually full brim of the waste-bin as illustrated in Figure 4.

Figure 4: Proposed IoT-based Waste-bin Management

The system is simple to maintain and cost effective because the cloud server used was not developed and hosted. Secondly, it reduces human effort to monitoring the status of the waste-bin online as the system keeps automatic updates of the waste-bin at a specific interval of time. Hence, therefore, the proposed system has been able to monitored and analyze the waste collated from the proposed waste-bin in a higher institution. This has proven the efficiency of our system in monitoring waste of a sampled waste-bin.

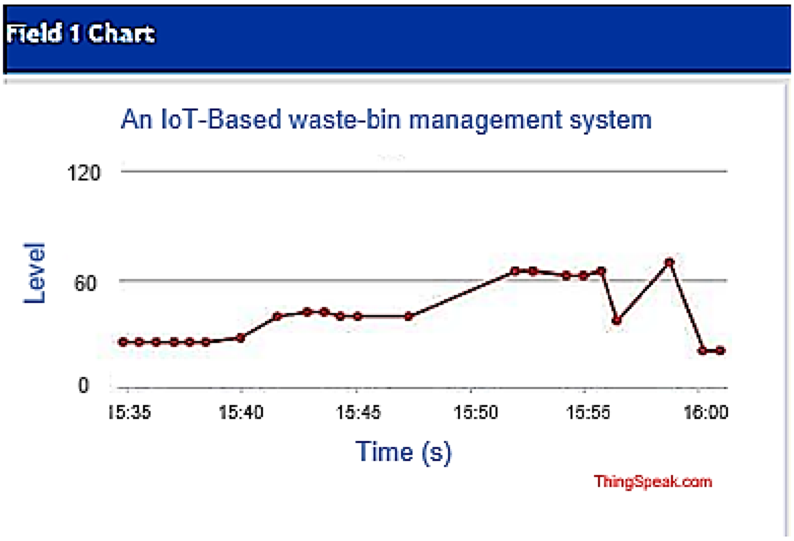

Figure 5: The Result of Collated Sensor Data on Thingspeak

Conclusion

The implementation of IoT-based waste-bin management system has been achieved. The adoption of IoT-based waste-bin management system would no doubt improve the hygiene and safety of higher institutions in Nigeria. The research on IoT-based waste-bin management system has provided an affordable and dependable system worthy of usage on our campuses. The result on the plotted graph have indicated an increase variation of 25% to an approximate 75% of filled waste-bin. The graph have demonstrated the efficiency of the system in monitoring of waste from the proposed waste-bin. The system can be improved by making the system more intelligent through the incorporation of a surveillance camera, short messaging system (SMS) notification and global positioning system (GPS) technology for bin location. The camera can be used to upload the pictorial situation of the waste-bin and the environment while SMS notification and GPS provides the coordinate location and SMS alert to the authority and the residence on the status of the waste-bin. Also, a customer complaints module can be added to register all complaints and issues faced with the waste-bin for proper service delivery.

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