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IOT BASED SMART WASTE BIN MODEL TO OPTIMIZE THE WASTE MANAGEMENT PROCESS

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Abstract

Waste management has become one of the crucial universal problems at present. The rapid growth in world population, their complex living styles and the rate of urbanization have increased the amount of solid waste produce. Therefore, having a proper monitoring mechanism is a must to manage the situation. This paper suggests a solution to enable the society to automate and optimize waste management process using Internet of Things (IOT) technologies. The proposed solution will notify the user and other authorities when the waste bins are getting filled or when there is an unusual condition inside the bins like having high temperature or high humidity. Users can take necessary action based on the details. Researchers have used the layered architecture to develop this model and the main objective of the project is to gather waste collecting data and inform householders and relevant authorities online. The proposed model provides dashboard, sound and light alerts in the system.

Key words: IOT, Smart Bin, Sensors, Sensor network, Waste Management

Introduction

Over the decades, human had their own ways of waste management mechanisms at household levels. They had simple life styles in which everything consumed was environmental friendly. The wastes produced at households were in small quantities and biodegradable. The houses had enough land space where the residents were able prepare garbage pits. Over the time, the waste turned into compost and was used in plantation as a fertilizer. The whole process was environmental friendly and sustainable.

Eventually, with the increase in population people tend to move into cities looking for better living standards. Land areas used to build houses became limited to a few number of perches and the goods/products consumed are readymade wrapped in artificial materials like polythene or plastics. In such a situation, it is unable to manage waste as done in the past. Thus, people tend to dump garbage into surrounding natural environments or waste disposal sites maintained by government authorities, however, garbage is not separated in either case. Due to the large population within city areas, the amount of garbage dumped into these places is increasing daily. The municipal solid wastes are generated in large quantities creating many social and environmental issues in many countries, including Sri Lanka.

Solid waste management is one of very important services every city government provides for their residents. While service levels, environmental impacts and costs vary dramatically, solid waste management is arguably the most important municipal service and serves as a prerequisite for other municipal action.

Waste collection is the collection of solid waste from the point of production (residential, industrial commercial, institutional) to the point of treatment or disposal. Municipal solid waste is collected in several ways:

- **House-to-House:** Waste collectors visit each individual house to collect garbage. The consumer generally pays a fee for this service.
- **Community Bins:** Consumers dump garbage in community bins that are placed at fixed points in neighborhood or locality. The waste is picked up by the municipality, or it's designated, according to a schedule.
- **Curbside Pick-Up:** Consumers leave their garbage directly outside their homes to be collected by a garbage pick-up schedule arranged by the local authorities.

- **Self-Delivered:** Generators deliver the waste directly to disposal sites or transfer stations, or hire third-party operators (or the municipality).

Though government authorities have implemented mechanisms to collect waste still it has loopholes. As estimated, waste generation in the country ranges between 0.4 – 0.85 kg per person and the total waste generation is estimated to be 6400 tons a day whereas waste collection is only about 3470 tons a day (*Sri Lanka Sustainable Energy Authority*/ *Waste Analysis*). Until collected, waste just piled up in bins or at surrounding areas. Uncollected solid waste contributes to flooding, air pollution, and public health impacts. There is no mechanism to inform the authorized parties about the sources where the waste is piled up, so, they can visit those places and pick up waste immediately.

To address the problems related to waste collection, this paper discusses a modern waste management system using Internet of Things (IoT). IoT is a concept of connecting any device to the Internet and to other connected devices. The IoT is a giant network of connected things and people – all of which collect and share data about the way they are used and about the environment around them. The authorities involved in waste management are beginning to develop and implement IoT-related solutions. The proposed IoT Smart Bin model is equipped with sensors and will make predictions based on the measurements gathered from the sensors. The model provides intelligence to waste bins which notifies the authorized parties about the waste collected locations.

Literature Review

The management of waste has become more complex due to the amount of waste daily generated. The facilities provided by the municipal council and other local authorities cannot handle the increasing demand and needs. To increase the efficiency of waste collection efficiency, a modern approach needs to be implemented considering environmental, social and economic aspects. Many researches have been conducted under waste management both internationally and locally, where the authors attempt to give solutions to existing problems.

In the book "Interconnecting Smart Objects with IP" (Vasseur, J., & Dunkels, A., 2010) has explained the importance of smart cities. "The integration of Information and Communication Technology (ICT) with development projects can change the urban landscape by developing Smart Cities. Smart Cities can dramatically improve the citizens' quality of life, encourage businesses to invest, and create a sustainable urban environment". Smart cities are the next evolution in human habitation. In this situation human-beings will be surrounded by sensors and actuators within the context of Internet of Things.

The researchers in "Solid waste management challenges for cities in developing countries" (Guerrero, L. A., Maas, G., & Hogland, W., 2013) stated that mainly due to the increasing generation of waste, the burden posed on the municipal budget as a result of the high costs associated to its management, the lack of understanding over a diversity of factors that affect the different stages of waste management and linkages necessary to enable the entire handling system functioning."

According to the World Bank report "What a Waste: A Global Review of Solid Waste Management" (The World Bank Group) the criticality of the problem at the global level is shown. "Current global MSW (Municipal Solid Waste) generation levels are approximately 1.3 billion tons per year, and are expected to increase to approximately 2.2 billion tons per year by 2025." Further the report states the link between the level of economic development and the amount of waste produced, Solid waste is inextricably linked to urbanization and economic development. As standards of living and disposable incomes increase, consumption of goods and services increases, which results in a corresponding increase in the amount of waste generated.

In the paper "IGOE IOT Framework for Waste Collection Optimization" (Lokuliyana, Jayakody, Rupasinghe, & Kandawala, 2017), focused on implementing a waste management system using an IOT Based framework. As the research outlines, they propose a layered architecture to handle the waste collection process where an optimization algorithm is derived for the existing business process. The proposed sensor based system attempts to achieve higher efficiency and lower latency by implementing this IOT Based Framework in the current waste management process.

The paper “Research on Application of IOT in Domestic Waste Treatment and Disposal”(Wang & CAO, 2014) discussed about the application of IOT in domestic waste management focused on waste traceability, dynamic trajectory tracking and parameter monitoring which will support to improve waste management process. The paper outlines the use of RFID, GIS and GPS technology and sensor network in identification of waste sources and monitor tracking. The researchers have been able to make some achievements and also pointed out some off the technical problems encountered such as low power consumption, low cost, miniaturization of wireless sensors, and coordination of technical standards.

The paper “Municipal Solid Waste Recycle Management Information Platform Based on Internet of Things Technology” (Tao & Xiang, 2010), studied about the current research situation of Municipal Waste Management (MWM) of Wuhan, the center of central china’s largest city. Based on the studies conducted, it identifies the current waste disposal problems and proposes a framework of waste cycle management information platform based on Internet of Things (IOT).

The paper “WECO: A Wireless platform for monitoring recycling point spots” (Gomes, Brito, Mendes, Cabral, & Tavares, 2012), studied about the usage of wireless sensor networks on waste management. The paper proposes a wireless embedded solution for monitoring the waste level of the bins located in recycling spots. According to the experiments conducted by the researchers, proposed platform performed as a good solution for a low cost, low power wireless monitoring system.

Although considerable amount of efforts have been made by many researchers and other entities tackling and improving waste-management problems, still major gaps can be identified in research domain. Within Sri Lanka, the waste management operators, do not use proper monitoring mechanism to manage the situation. Adding a bit of modern technology to our waste bins will solve most of our problems in the process and the smart-bin has a lot of advantages. Even the paper “IGOE IOT Framework for Waste Collection Optimization” proposes a framework; still there is no implemented system to overcome waste-management problems. The prototype model proposed by the authors of the “IOT Smart Waste Bin Model” comes up with an implementation model which can be used to maintain the hygiene level at the places where the waste are being produced on continuous basis. Further it is needed to maintain a higher level of hygiene in hospitals, hotels, markets.

Methodology

The proposed IOT based Smart Waste Bin Model consist of Data Gathering Layer (DGL), Data Processing Layer (DPL) and Data Demonstration Layer (DDL). As shown by the following figure, the Data Gathering Layer (DGL) consists with different types of sensors used to take the measurements from the waste bin. The sensor readings taken by the Data Processing Layer (DPL) which uses a micro controller (Raspberry Pi module) for the processing. According to the logics defined, the Smart Bin Model will make predictions about the temperature level, humidity level and the capacity of the waste bin. The MQTT protocol, handles the message transmission between the micro controller sub system and the dash board. The Data Demonstration Layer (DDL) consists with Alert Notification Sub System and a Dash Board. The Alert Notification Sub System (ANS) consists with different types of indicators which show the temperature level, humidity level, remaining waste bin capacity level and a sound buzzer to alert the waste collecting parties about the status of the waste bin. The Dash Board visualizes the sensor measurements and the notifications to the authorized parties.

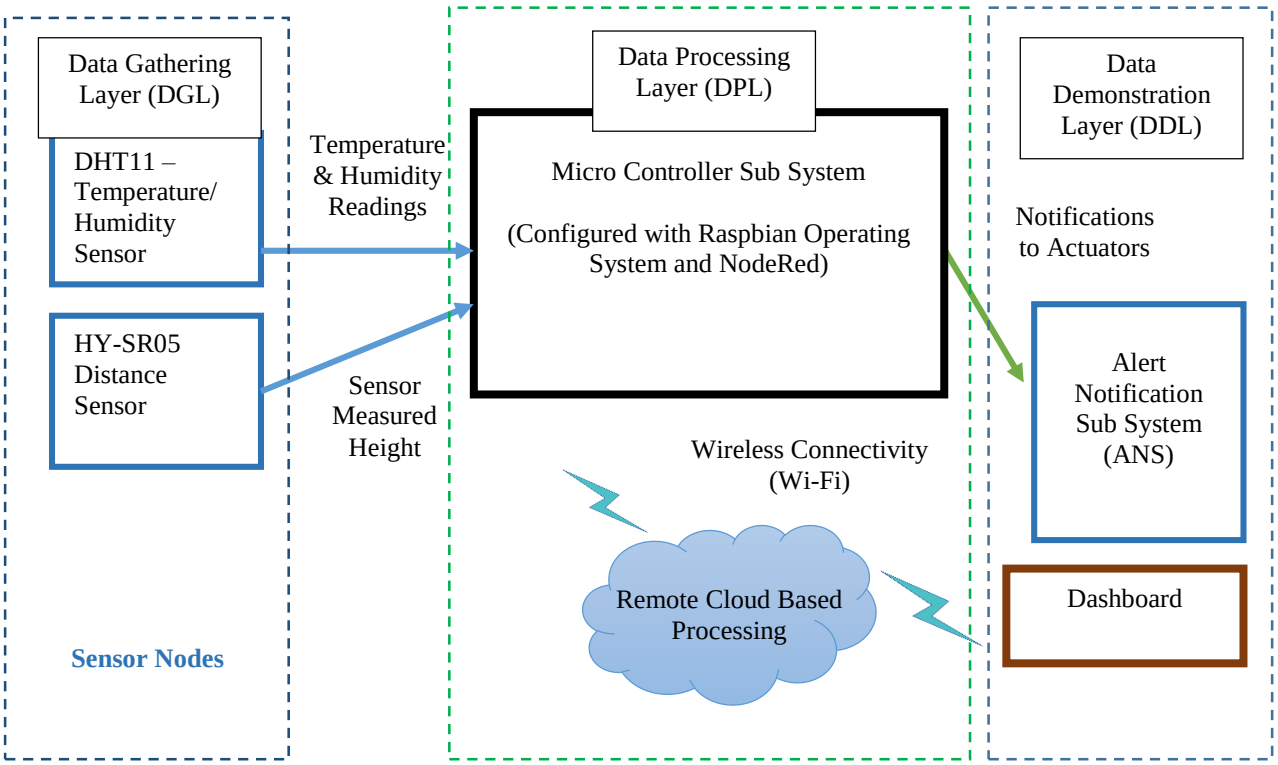

Fig. 1 System Overview of IOT based Smart Waste Bin Model

A. Data Gathering Layer (DGL)

The IOT Smart Waste Bin Model developed to be deployed in legally authorized pre-defined waste disposal areas situated around the country. When designing the model mainly the authors were focused on making a prediction system based on the remaining waste in bins.

The main objective of this simulation module is to deploy a sensor based network into authorized waste disposal areas so it will gather data from sensors to make predictions about the waste levels and develop a notification system which will inform the local authorities about highly prioritized waste collecting sources.

Different types of sensors (DHT-11, HY-SR05) used to collect the data from the waste bin which is equipped with the Raspberry Pi module. The DHT-11 sensor is used to measure the temperature and humidity level of the waste leftover inside the waste bin. The ultrasonic distance sensor (HY-SR05) used to measure the filled level of the waste bins.

The data which taken from the sensors are transferred to the Data Processing Layer (DPL) to analyze and visualize them using the Data Demonstration Layer (DDL).

B. Data Processing Layer (DPL)

The micro controller uses Node-Red, which is a programming tool that comes with the raspberry pi used in wire hardware devices, APIs and online services that support IOT Applications.

Node-Red (*Node-RED , Flow-based programming for the Internet of Things*.), uses different types of node flows and according to the type of sensors connected with raspberry pi unit, it collects the data transferred and analyzes the data to make the predictions according to the Logic defined to the flows.

The data transferred by the sensors are analyzed by the micro controller at this point. The controller takes the DHT-11 sensor measured temperature and humidity level (*DHT11 Product Manual*) of the smart waste bin. When the waste inside the bin degraded it produces gases like ammonia which

results in increasing temperature level. Most of the waste bins located by the waste collecting parties are closed with a lid. When the temperature level increases due to the gases retain inside and need to take necessary proactive actions based on the details, to prevent any accidental damages. The humidity level inside the bin measured is to inform the ambient condition of the bin owing to ensure about the proper functioning of other sensors. With high humidity the fungus reaction increases while producing unpleasant smells in surrounding. Notifying the measurements will prevent to such situations.

The HY-SR05 sensor (*HC-SR05 / HY-SRF05 Precision Ultrasonic Distance Sensor*) is used to measure the filling level of the smart waste bin. When the sensor reading taken by the controller, according to the remaining capacity of the bin, it will inform the percentage of the filling level to the authorized parties.

MQTT protocol (*MQTT Protocol,for MQ Telemetry Transport.*) is used by the IOT module within the Data Processing Layer. MQTT is a machine-to-machine (M2M)/"Internet of Things" connectivity protocol. It was designed as an extremely lightweight publish/subscribe messaging transport.

MQTT uses a topic based mechanism, where according to the data gathered from the sources (sensors) the MQTT publisher, publishes the topics according to the sensor readings in to MQTT Broker, when needed the MQTT Subscribers (authorized parties) will make a connection with the MQTT broker and take the topics for its use as shown by the figure 02.

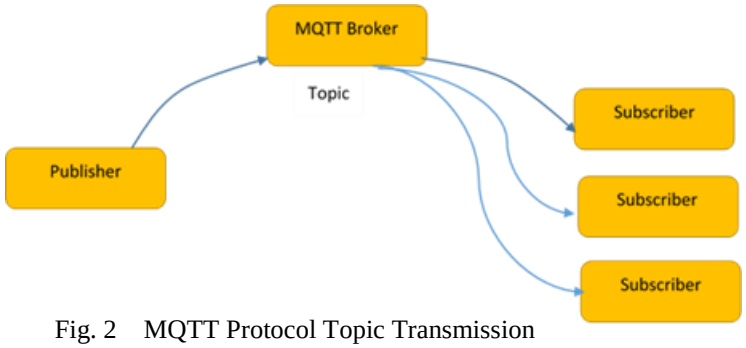

Fig. 2 MQTT Protocol Topic Transmission

When the MQTT server gets the data from Data Gathering Layer (DGL), it publishes the topics to the MQTT Broker. According to the threshold levels defined for the temperature, humidity and filling level the alert messages will be sent by the MQTT broker to the MQTT subscribers informing the critical level of measurements (temperature/humidity/bin capacity).

C. Data Demonstration Layer (DDL)

The IOT Smart Waste Bin module developed to make predictions, based on the data collects from the sensors. It uses a cloud based platform to integrate Smart Waste Bins and the authorized parties (subscribers). The sensor measurement visualizes the user by integrated online dashboard where subscribers can get connected. Charts, meters, indictors which show temperature readings, bin capacity level and humidity readings are shown similar to figure 03.

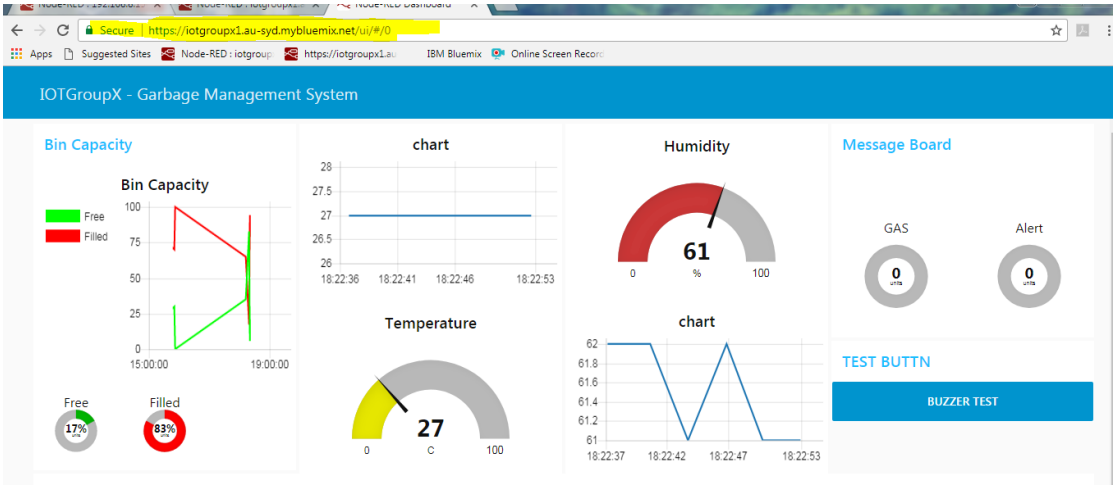

Fig. 3 Data Visualization Dashboard

The algorithms defined to the MQTT flows used to identify the highly prioritized waste disposal places so the authorized parties can visit those places to collect the waste into vehicles used.

The prediction algorithm is as follows,

1. *While (sensor published the topic about reading = true)*
2. *If high priority level set = true*
3. *Mark the waste disposal location*
4. *Send an alert message to activate actuators*
5. *Monitor the status respond*
6. *Else*
7. *Visualize the current status to the dash board (Sensor Readings)*

Periodically, the sensors connected to the IOT Smart Waste bin model give the readings to the MQTT sever configured in Cloud Based System. According to the logics defined by the Node-Red flows, it analyses the readings and give the responses accordingly. When the measurements are in the critical level the notifications will be sent to the local authorities informing the wastes need to be collected from the particular locations.

The figure 04 depicts flow diagram of IOT Smart Waste Bin Model. The sensor measurements will be continuously fed to the MQTT server and the system will update dash board accordingly.

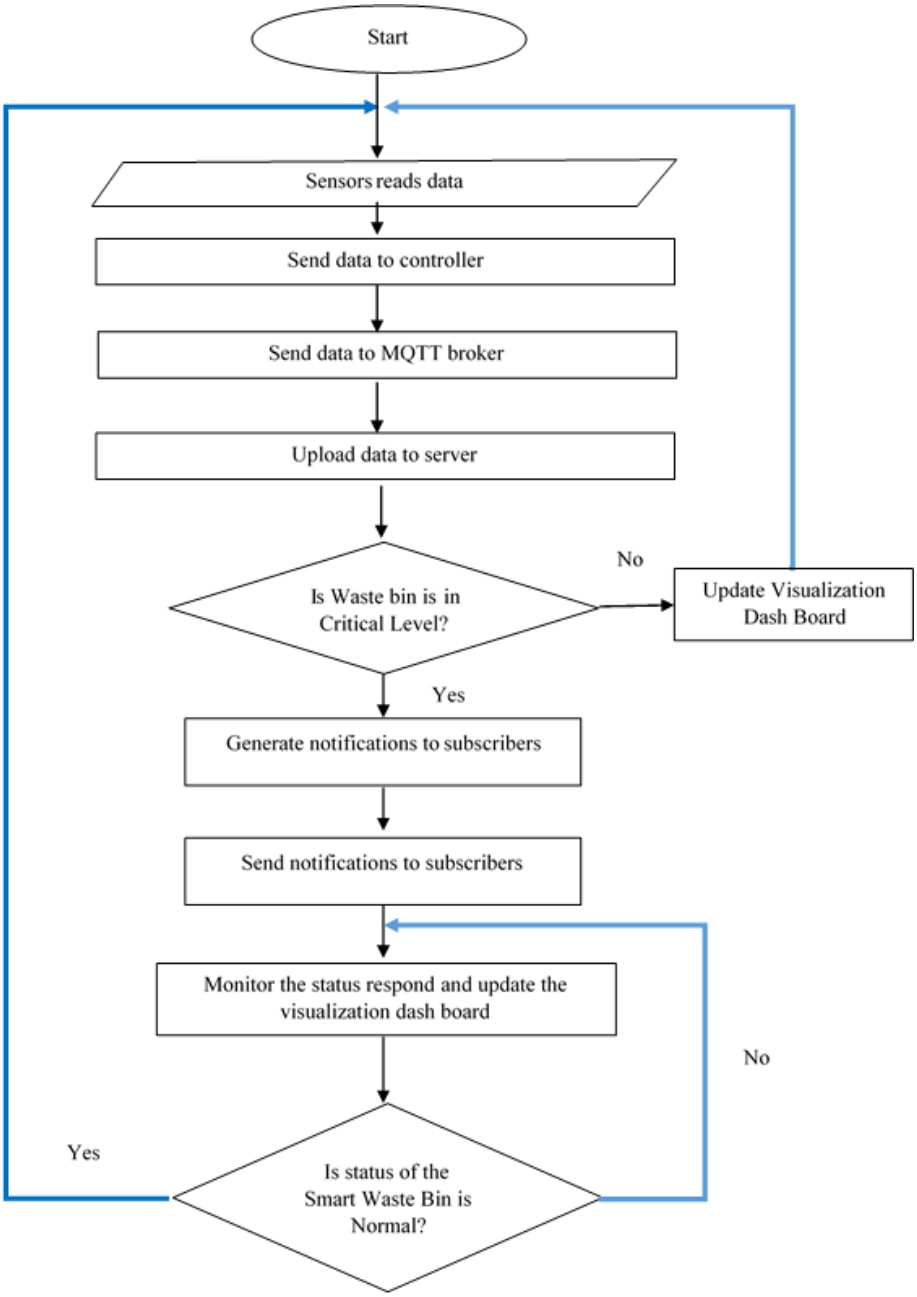

Fig. 4 Flow Chart of IOT Smart Waste Bin Model

4. Result and Discussion of the Prototype Model

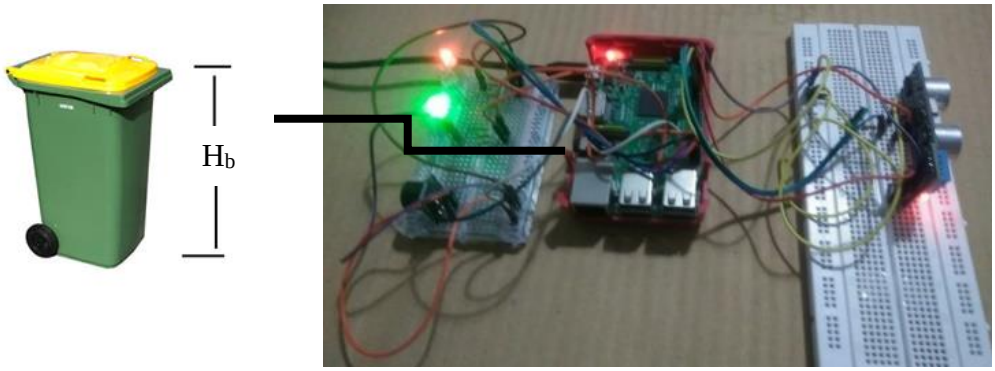

Fig. 5. IOT Module Integrated to the Smart Waste Bin

The IOT Smart Waste Bin model equipped with sensors detect the measurements and node transfers to the MQTT Server, where the height is measured using the ultrasonic sensor, through the following equation (1) the MQTT Server calculates the remaining capacity of the waste bin.

$RC = H_b - S_h$ (1)

RC - Remaining Capacity of the bin

H_b = Height of the bin

S_h - Sensor Measured Height

When the RC <= Critical Level, the MQTT Publisher sends an alert message notifying the bin capacity level. Using the test data shown by the table 1 the distance sensor (HY-SR05) connected to the IOT module tested to verify the states of the notifications.

Table 1 : Distance Sensor Bin Capacity Test Data

Status	RC %	Test Data (cm)	Respond of IOT Module
Normal	> 30%	100, 75, 45	No Alert, visualize current status to dash board
Critical	<= 30 %	30, 28, 25	Sound Alert, Red LED indicator and Alert Notification sent to MQTT Subscriber
Full	= 0 %	0	Sound Alert, Red LED indicator and Alert Notification sent to MQTT Subscriber
Ignore	-	> 100	Discard the measurements

According to the DHT-11 sensor temperature measurement (S_t) based on threshold temperature level (T_{tl}). Using the test data shown by the table 2 the temperature sensor (DHT-11) connected to the IOT module tested to verify the states of the notifications.

Table 2: Temperature Level Measuring Test Data

Status	temperature measurement (S_t)	Test Data (°C)	Respond of IOT Module
Normal	$< T_{tl}$	32, 34, 37	Green LED Indicator, visualize current status to dash board
Critical	$>= T_{tl}$	75 - 85	Sound Alert, Red LED Indicator and Alert Notification sent to MQTT Subscriber

As explained in the methodology, the IOT Smart Waste Bin prototype model responded successfully with expected results.

Conclusion & Recommendation

The authors of the IOT Based Smart Waste Bin model proposes a prototype model which can be implemented as a monitoring and notification system the municipal operators can use to realize the tractability of the waste sources. The Smart Waste Bin model can be introduced into places where the higher level of hygiene environment should need to be maintained such as hospitals, hotels, supermarkets and many more. This model can be used as a sensor node to an integrated waste management system runs in cloud or fog system environment. The collected information can be used to optimize and reduce human resources, equipment used and plot optimizes routes for collecting vehicles reduce operation cost than right now.

As future work, other type of measurements such as toxic gas levels, radiation level inside the waste bins and weight of collected solid waste can be also detected or measured by integrating relevant sensors to the proposed model accordingly.

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