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A Detailed Study on Smart Waste Monitoring Systems, an Application of Internet of Things

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Abstract: ***Solid waste management is currently a crucial problem in urban areas. The overflowing dustbins create an unsanitary state which can cause various health hazards including irritation in the nose, throat and lungs. To tackle these circumstances, effective management of waste is necessary. The Internet of Things (IoT) has influenced our world significantly. There has been a considerable amount of research in the field of Waste Management using IoT technology. This paper reviews various IoT-based approaches presented by different researchers for solving this problem, and it provides a comparative study of the available solutions.***

Keywords: Smart Waste Management, IoT, Raspberry Pi, Arduino, Ultrasonic sensor, IR sensor, Load sensor, RFID sensor

I. INTRODUCTION

The world population has been increasing by the day and as does the generation of waste which makes the handling of waste more tedious. The average amount of waste generated, worldwide, per day is 0.74 kgs per person, but ranges widely, from 0.11 to 4.54 kgs [1]. India alone generates between 0.2 and 0.6 kgs of garbage per person per day [2]. The waste generation per capita is so high that irregular disposal and collection of garbage can result in overflowing dustbins, indirectly leading to unhygienic surroundings that may result in the spread of diseases. Therefore, waste management has become a vital issue at hand.

Waste Management can be defined as the management of waste from its inception to its disposal. The waste management process is not economical in terms of money as well as human labour. The routes provided for garbage collection may not be optimized and can lead to wastage of resources like fuel, human labour, and time. To make the waste management process more economical, IoT technology can be employed which will help automate the process with minimal human intervention. The smart dustbins can be built at a very cost-effective rate since the actuators and sensors are not very costly. Along with this, many functionalities can be provided like the shortest route planning, data monitoring, etc. A smart system will reduce human efforts considerably, consumption of fuel, and most importantly it will help keep surroundings clean. In this paper, we have discussed the present IoT systems in section II in which section II[A] consists of all the smart waste management systems that use Arduino as a microcontroller, section II[B] consists of all the smart waste management systems that use Raspberry-pi as a microcontroller. In section III we have discussed the merits and demerits of the systems discussed in the previous section. Finally, we conclude our study in section IV and talk about the future scope in section V.

II. IOT-BASED WASTE MONITORING SYSTEMS

A. Smart Waste Monitoring systems with Arduino Microcontroller

Muyunda and Ibrahim [3] proposed a smart garbage monitoring system based on Arduino that monitors the sensor data and provides route planning. Two types of sensors have been used, namely ultrasonic sensor and tilt sensor. The ultrasonic sensor detects the garbage level in the bin and the tilt sensor detects whether the bin is in an upright position or not. The data from these sensors are collected by the microcontroller, Arduino Nano. This data is then uploaded to the MySQL database using the Wi-Fi module, ESP-8266. The system is powered using batteries, and to provide power efficiently to every component step-up and step-down converters are used. To make the system power-efficient and enhance battery life, real-time data monitoring is not carried out. Instead, the sensors directly communicate to the server as a single-hop network with flat architecture was selected for the sensor network, the sensors store the data if there is an issue with uploading data in the database. Each sensor node has a unique ID with the help of which each bin is identified. The data collected by these sensor nodes is presented on a website where bin color changes according to the fill level of the dustbin. The bin icon is green, yellow, and red if the level is below 30%, between 30-70% and above 70% respectively. This is done to show the priority of dustbins, so the route planning can be planned accordingly. The route planning algorithm considers the location of the bin, the color of the bin and the initial location of the garbage collecting vehicle and provides the optimized route.

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Mirchandani et. al [4] proposed a smart waste management system that allows real-time garbage monitoring and also provides an optimized path for garbage collection. The proposed system is categorized into three units namely, Data Generation Unit, Data Processing Unit, and Application Unit. In the Data Generation Unit, the data from the ultrasonic sensor that detects the level of garbage in the bin, the data from the toxicity sensor that detects the gases present in the bin, and information of RFID tags is collected by the Arduino Uno and sent to the server. In the Data Processing Unit, the data received from the microcontroller is given to an algorithm that decides which bins need to be collected and updates the list of services accordingly. Then from the list, the total weight of waste is calculated by the algorithm and the number of trucks and type of trucks (high capacity or low capacity) is selected. A cluster-based algorithm is used to select dustbins for collection, which considers neighboring dustbins as clusters. A top-k query-based algorithm is used to select the clusters for garbage collection, based on the data parameters of the trucks. Then, according to the cluster, suitable capacity trucks are selected. Using Dijkstra's algorithm, the shortest path from the current location of the truck is determined. Two applications are designed, one for users to maximize their engagement by rewarding points that can be redeemed later, and another for truck drivers to locate the clusters through the provided route for a particular truck. This system provides an efficient waste collection plan.

Suryawanshi et. al [5] have developed a smart garbage clearance alert system that alerts the municipal web server after the fill level in the trash bin crosses the threshold. The ultrasonic sensor has been used to detect the fill level, if the level crosses the threshold an alert message is sent to the concerned authority, the message is sent using the GSM module. Arduino Uno is the microcontroller used as an interface between the sensors and server. The microcontroller reads the data from the sensor and sends it to the web server, this allows real-time monitoring of the waste. After sending an alert message the authority sends a garbage collecting vehicle to collect the garbage. This process is iterated until the garbage gets collected. The driver, after collecting the garbage, confirms the collection process with the help of an RFID tag which updates the status of the collection. Along with the webserver, an application has also been developed that sends notifications using a Wi-Fi module.

A Patel and N Patel [6] have developed an IoT-based management system for garbage that tracks the amount of garbage in containers and send the data via SMS to approved staff. They have used NodeMCU, ultrasonic sensor, geolocation API and IFTTT service for their project. NodeMCU gives instruction to the ultrasonic sensor which calculates time. Then distance is calculated using time. If the distance is more than the threshold value (70%), then the latitude and longitude of the location will be calculated with help of geolocation API via the IFTTT service. After this IFTTT will generate a message which will include the level of waste and location of the bin and this will be sent to the desired worker.

Sinha et. al. [7] have designed a Garbage Monitoring System using IoT. They have used Arduino Mega, ESP8266, ultrasonic sensor, LCD and Blynk app. They have assigned a unique ID to every bin. Every dustbin has an ultrasonic sensor. The ultrasonic sensor is used to measure the fill level of the garbage. The ultrasonic sensor is interfaced with Arduino Mega. The Arduino Mega is a microcontroller board based on the ATmega2560. This system will be connected to the internet through the ESP8266 Serial Wi-Fi wireless transceiver module. It is a wireless network microcontroller module. The level of dustbins can be monitored on the Blynk app which is connected to the entire system. LCD will also display the ID and level of dustbins along with the location from time to time.

B. Smart Waste Monitoring Systems with Raspberry Pi Microcontroller

Mahajan et. al. [8] proposed an IoT-based system for waste management that detects the fill level and monitors the fill level of specific garbage bins. The proposed system has a master-slave configuration to avoid connectivity issues. The master bins are provided with Raspberry-pi and the slave bins are provided with IoT modules. Each master and slave bin is given a unique id and the placement of these bins depends upon the corresponding ids.

The proposed system makes use of an ultrasonic sensor, load cell, humidity sensor i.e. DHT11 and Raspberry-pi. An ultrasonic sensor has been used to calculate the garbage level in the bin and when the level exceeds the threshold an alert is generated. The load cell has been used to detect the weight of the garbage bin. The ultrasonic sensor and load cell, when used together provide greater accuracy in the generation of an alert.

A humidity sensor has been used to detect dry and wet waste. The data received from the sensors attached to master and slave bins is then processed by the microcontroller, Raspberry-pi. Then the Raspberry-pi applies a noise removal algorithm and, using the Wi-Fi module, ESP8266, sends the data to the server. The data analysis is done using the tools like Storm or Hadoop and an accurate report is generated. Along with this, an optimized route is also provided using Google maps which is advantageous in saving fuel and indirectly reduces cost.

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Singh et. al. [9] proposed an IoT-based waste collection system intending to provide optimized waste collection routes. The proposed system uses 4 infrared sensors attached to the top of the bin; Raspberry-pi which acts as an interface between bin and server which is a Django-based Python web application. The sensors read the level of garbage in the bin and send the data to the Raspberry pi which sends this data to the web app using the GSM module. In this system, Infrared sensors are used instead of ultrasonic sensors because of their faster response time. The web framework processes all the updates from various bins and places their location on the map, and then provides an optimized route and schedules collection plan. One of the striking advantages of this system is that it works well with a dustbin without a lid or a hinged dustbin etc, making it most efficient to use in Indian cities.

Pathak et. al. [10] proposed a garbage level monitoring system using Raspberry Pi which monitors the real-time fill level information of dustbins. The proposed system uses ultrasonic sensors to measure distance, Raspberry Pi board and ESP 8266 Wi-Fi Module. When the entire system is enabled and Raspberry Pi is supplied with power, the program runs and triggers the ultrasonic sensor. The ultrasonic sensor measures the fill distance using a reflection mechanism. The outcome is given to the server as ESP 8266 connects to the internet. This gives the admin a detailed analysis of the garbage level of all the trash bins on the server dashboard. They can view the status of all the dustbins from one place and take necessary actions. This system used Django and Python-based dashboard for the purpose of monitoring garbage bins. The dashboard makes use of Google charts for visualization and is connected to an SQLite database where all the data is stored. This system helps to simplify the process and reduce manpower wastage.

Patra et. al. [11] proposed an IoT-based garbage management system for the smart city using Raspberry Pi. The proposed system uses three kinds of sensors which are an ultrasonic sensor, load sensor and gas sensors. On top of the waste bin, the ultrasonic sensor is attached which measures the fill level and four load sensors are also placed next to it. The signal from the load sensor is converted into a digital signal from an analog signal using an analog to digital converter. This signal is sent to the node sensors which send the data to the communication protocol. The ZigBee protocol receives the data from the communication protocol. The ZigBee prevents simultaneous messages. The gas sensors are used to detect the odor of the dustbins. The data of the dustbins is stored in the MySQL database which is installed on Raspberry Pi. The board has an ethernet interface which functions as a basic data web server. This system allows the user to monitor the bins from a web browser and the garbage collector can collect the garbage on time.

Jenisha et. al. [12] proposed a garbage management system using Raspberry Pi, three types of sensors and GPS. The sensors used in the proposed system are an ultrasonic sensor, IR sensor and gas sensor. The distance of the garbage in the bin is measured using an ultrasonic sensor. IR sensor is used to count the number of items thrown into the bin. Gas sensors are used to detect the smell. When any gas comes in contact with the gas sensor, the sensing element adsorbs the ionized components of the gas. This generates an electric potential in the sensing element which is sent in the form of current to the output pin. The GPS is used to feed directions of the garbage bins. This system uses Raspberry Pi 3 which is connected to other devices and installed on the computer. All the sensors send value to the Raspberry Pi and then it decides whether mail is to be sent to Municipal Corporation or not. This system reduces the need for human intervention in the process of garbage disposal.

III. DISCUSSION

Various IoT-based smart waste management systems were discussed in this paper. Mainly devices having Arduino and Raspberry-pi as microcontrollers were discussed. Table 1 and Table 2 provide the merits and demerits of systems using Arduino and Raspberry-pi as their microcontroller respectively. Using Raspberry-pi microcontroller can help provide more functionality to the smart system, data mining and machine learning techniques can be implemented to make systems more efficient.

TABLE.1 Merits and Demerits Of Arduino Systems

Papers	Merits	Demerits
Muyunda and Ibrahim [3]	● The exact location of the bin can be found as Route planning is provided ● Power efficiency is high as the Buck and Boost converter is used ● Sensor nodes can also store the records if the database connection is lost and after re-establishing the database connection, the stored data is uploaded	● No feature is implemented to collect the garbage from bins that are below the specified level ● Real-time monitoring of garbage bins is not carried out

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Mirchandani et. al [4]	• Real-time monitoring of garbage dins is done • The collection process is highly optimized	• Power consumption of the system is high due to many sensors used
Suryawanshi et. al [5]	• RFID tags can distinguish the type of garbage filled and it also sends the status of collection of garbage completed to the server. • The system keeps on sending alert messages via the GSM module until the garbage is collected.	• The records are not stored in a database. • The methodology is not explained quite well.
A Patel and N Patel [6]	• The exact location of the dustbin can be found as the project uses geolocation API is used • It is cheaper as the project is entirely based on NodeMCU	• The project uses NodeMCU and the voltage level of NodeMCU is 3.3V. Hence, any 5V Module can reset NodeMCU. • NodeMCU consumes more power • Data is not stored anywhere; therefore, only live monitoring can be done.
Sinha et. al. [7]	• As the project uses Arduino Mega, the power consumption is less. • Unique IDs have been used for dustbins, which makes the collection process easier.	• No service has been used to detect the location of the dustbin. • Data is not stored anywhere; therefore, only live monitoring can be done.

Table 2
Merits and Demerits Raspberry-PI Systems

Papers	Merits	Demerits
Mahajan et. al. [8]	• An optimized route is provided ensuring the fuel consumption is minimal • Real-time monitoring of fill level in the dustbins is done • The level of dry and wet waste in the bin is determined	• The functions and usability of the web application is mentioned inadequately • This system uses Wi-Fi module ESP8266 which limits its deployment range • Using a load sensor increases the overall cost of the system
Singh et. al. [9]	• It is a cost-effective system • It can be employed on dustbins without a lid • Route planning is also provided	• Using IR sensors instead of ultrasonic sensors do reduce the system cost but reliability of system is also compromised.
Pathak et. al. [10]	• Dustbins can be remotely monitored from any location. • It reduces manpower wastage by minimizing the number of visits of the garbage collectors. • Visualization tools help in keeping track of garbage bins.	• The location of dustbins cannot be found. • Dustbins only in the small range can be monitored as Wi-Fi Module is limited to the Wi-Fi range.
Patra et. al. [11]	• Remote monitoring of dustbins can be done on a web browser from anywhere. • A hygienic environment is being created as the system is also measuring the odor using the gas sensor.	• As there are so many sensors, more power supply is needed. • The location of the dustbins can't be found.

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Jenisha et. al. [12]	● Dustbins can be monitored remotely from everywhere. ● The location of dustbins is available with the help of GPS. ● Bad smell is prevented as the gas sensor measures the odor.	● More power is consumed as a lot of sensors are used.

IV. CONCLUSION

The waste monitoring system is among the most critical systems that contribute to environmental change by preventing garbage overflow in the bins and foul odors. This analysis of various systems reveals that the Internet of Things has significantly improved the consistency and reliability of waste management systems, as well as contributed to public health response. The use of Arduino and Raspberry Pi in these systems has resulted in a more cost-effective and long-lasting waste management process. Both Arduino and Raspberry Pi have their own benefits and drawbacks, but depending on the location and circumstances, one should select the system which is most convenient and appropriate.

V. FUTURE SCOPE

Since the requirements for this project are easily available for engineering needs, we aim to develop a smart waste monitoring system by ourselves and would like to see innovative ideas emerge in the future.

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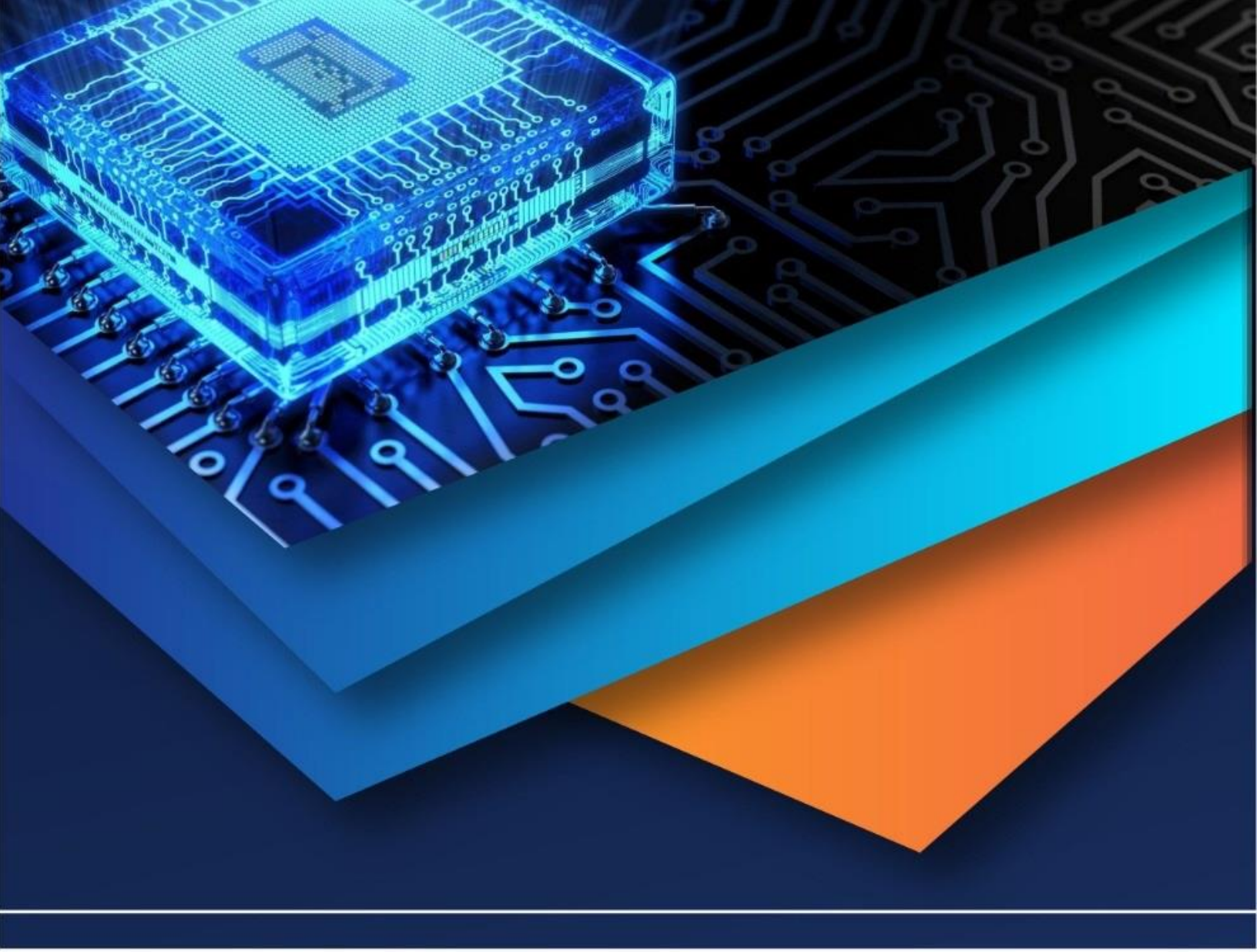

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