VIT®

Vellore Institute of Technology

(Deemed to be University under section 3 of UGC Act, 1956)

Internet of Things

CSE3009

Project Report
Smart solid waste management using IoT and cloud computing

Submitted by

Deep Zatakiya 18BCE0090

Amrita Bose 18BCB0054

Prateek sinha 18BCB0081

Anshuman Gupta 20BCE2119

Aditi Jain 20BCE0721

Under the guidance of

Prof. Dheeba J

Contents

1. **Introduction**
    - 1.1. Aim
    - 1.2. Objective
    - 1.3. Benefits
2. **Literature survey on existing systems**
    - 2.1. Sensor Selection
    - 2.2. Hardware setup
    - 2.3. Software/technologies used
    - 2.4. Cloud analytics/processes
    - 2.5. Use cases
3. **Proposed system model**
4. **Results and Discussion**
    - 4.1. Algorithms to overcome the issues
    - 4.2. Analysis of the algorithms
        - 4.2.1. Cuckoo Search Algorithm
        - 4.2.2. Enhanced Route Selection Algorithm
        - 4.2.3. YOLO Algorithm
5. **Conclusion**
6. **References**

1. Introduction

1.1. Aim

Many metropolitan cities produce tons of waste every day, so efficient methods for collection and disposal are crucial. To make people's lives happier, safer, and healthier we developed an IoT prototype. The Internet of things (IoT) plays a vital role in connecting human life with machines and the internet.We developed a collection management system by fixing our prototype onto the dustbins, and now they can be called Smart Bins. Our IoT prototype consists of a sensor, microcontroller, and a Wi-Fi module. It collects data from sensors and passes it to the cloud via the internet. It measures the filled levels of the waste bins, if the bins are full then it sends an alert message to the organization/controller stating "Bin is completely filled" and it also predicts the future levels of the bin.

Keywords: Internet-Of-Things (IoT), Smart waste management, cound, Machine learning, Future prediction.

1.2. Objective

Waste management is a problem that we have been facing from a very long time, however recently the problem is not only about the physical space and decomposition but also proper disposal of harmful waste i.e. the E-waste and Bio-medical waste. There are two sub problems that come under the broader topic known as Solid waste management - first, figuring out what is recyclable/reusable/biodegradable and the second, what goes where. Now, one might ask why not put everything in landfills and cover them up? Or follow the careful disposal method for everything? The answer is, we simply cannot.
Certain categories of waste are too harmful for the environment to be put in landfills and certain categories can be easily recycled to save a lot of resources and disposal space.

All these problems call for an efficient way to identify the solid waste in different collection scenarios and deal with it accordingly. Looking at the amount of solid waste that is generated in a year world wide, it almost feels impossible to deal with. However the solution lies with simple sensors and IoT. We aim to review some research papers in detail along with their use cases, technologies used or hardware required, sensor setup, software requirements and cloud analytics/processes that talk about providing an efficient solution to the solid waste management problem.

1.3. Benefits

1. It saves time and money by using smart waste collection bins and systems equipped with fill level sensors. As smart transport vehicles go only to the filled containers or bins. It reduces infrastructure, operating and maintenance costs by up to 30%.
2. It decreases traffic flow and consecutively noise due to less air pollution as result of less waste collection vehicles on the roads. This has become possible due to two way communication between smart dustbins and service operators.
3. It keeps our surroundings clean and green and free from bad odour of wastes, emphasizes on a healthy environment and keeps cities more beautiful.
4. It further reduces manpower requirements to handle the garbage collection process.
5. Applying a smart waste management process to the city optimizes management, resources and costs which makes it a "smart city".
6. It helps the administration to generate extra revenue by advertisements on smart devices.

2. Literature Reviews

2.1. Solid Waste Collection as a Service using IoT-Solution for Smart Cities

Author - Sangita S. Chaudhari; Varsha Y. Bhole
Conference - 2018 International Conference on Smart City and Emerging Technology (ICSCET)
Year - 2018

This paper talks about a cloud based system for organizing solid waste management processes and mobile applications for waste collection drivers and Municipal Corporation to monitor and control solid waste collection as a service by facilitating the waste collection drivers to go to the garbage bins using a dynamic and shortest route.

Sensor Selection
Ultrasonic Sensors,Rfid Tags,GPS modules

Hardware setup
Ultrasonic sensors and GPS modules to indicate the location and level of garbage in the bin.
Microcontroller and RFID based circuitry is used to send the garbage bin status to the central cloud server.

Software/technologies used
Arduino IDE
Thingspeak
Android Studio

Cloud analytics/processes
The paper talks about sending the individual bin data to the cloud at regular intervals and processing the data on thingspeak. The proposed systems then use the google map package for dynamic routing and displays the most optimal route to collect filled bins efficiently across the city.

Use cases
This can be implemented in a city based scenario in collaboration with the local garbage collection facility eg. Municipal Corporation.

2.2. Smart city solid waste management leveraging semantic based collaboration

Author - Swarnalakshmi Ravi; Thanga Jawahar
Conference - 2017 International Conference on Computational Intelligence in Data Science(ICCIDS)
Year - 2017

This conceptual paper aims at developing a portal for a solid waste processing unit which needs the classified information regarding solid waste and the portal also enables the waste processing unit to collaborate with other satellite units and waste collectors for efficient and faster actions.

Sensor Selection
Virtual Concept - Parameters considered are Temperature factor and Environment Factors

Hardware setup
Virtual concept - Plans to use Barcode and RFID tags

Software/technologies used
Classification algorithms - CART trees technique
CRAN R- Programming language
SPARQL Query Language, OWL Web Ontology language and others.

Cloud analytics/processes
Implements semantic search and cloud based portal for WPU (Waste Processing units)

Use cases
It is a cloud portal/service for WPUs that helps channelizing of the waste processing units and waste collectors and other subsequent processing units, encourage quick decision and actions, facilitate more collaboration etc

2.3. Dynamic solid waste collection and management system based on sensors, elevator and GSM

Author - Trushali S. Vasagade; Shabanam S. Tamboli; Archana D. Shinde
Conference - 2017 International Conference on Inventive Communication and Computational Technologies (ICICCT)
Year - 2017

This paper talks about a smart solid waste management system that will check status and give alert of dustbin fullness and more significantly, a system has a feature to help literate people to use dustbin properly and to automatically sense and clean garbage present outside the dustbin.

Sensor Selection
IR Sensor Module
GSM Module

Hardware setup
It proposes a detailed mechanism with rolling shafts and set up for IR sensors in a product ready package where all the sensors are pre installed in the bin.

Software/technologies used
Does not declare clearly

Cloud analytics/processes
Does not declare clearly however it analyses the surroundings and sends capacity details to cloud

Use cases
Inside personal households.

2.4. Design and implementation of a smart solid waste monitoring and collection system based on Internet of Things

> **Author** - Aaditya Jain; Ranu Bagherwal
> **Conference** - 2017 8th International Conference on Computing, Communication and Networking Technologies (ICCCNT)
> **Year** - 2017

The paper talks about how the waste in the dustbins is checked with the help of Sensors used in the system, and information is sent to the required control room through the GSM/GPRS system.

Sensor Selection
GSM,GPRS
Microcontroller RL renesas 78
Ultrasonic sensor

LCD
Force Sensor
PIR Sensor

Hardware setup
A structured design concept is inherited and the system is mainly contains of microcontroller, Ultrasonic sensor, force sensor, GPS, GPRS, LCD, Amazon cloud web server and Android application

Software/technologies used
AWS and Android Studio

Cloud analytics/processes
The paper uses Amazon Web Services to achieve its analytics and processing

Use cases
It can be used on existing dustbins and just serves as an accessory

2.5. Design and Development of Smart Trash Bin Prototype for Municipal Solid Waste Management

> **Author** - Feisal Ramadhan Maulana; Theo Adhitya S. Widyanto; Yudi Pratama; Kusprasapta Mutijarsa
> **Conference** - 2018 International Conference on ICT for Smart Society (ICISS)
> **Year** - 2018

This paper describes the design and development of a waste management system intended for municipal areas which can differentiate between different types of waste and has a prototype to achieve the same.

Sensor Selection
Arduino UNO, Mega
Ultrasonic sensor
Capacitive and inductive sensor
Esp 8266

Hardware setup
The proposed system comprises a contraption where all these sensors have been installed in an accessory form and is ready to be mounted on an existing dustbin.

Software/technologies used
MQTT , Mosquito broker

Cloud analytics/processes
All processing takes place on the esp8266 and is sent through the MQTT broker.

Use cases
As an accessory on an existing dustbin.

2.6. IoT based solid waste management system for smart city

> **Author** - Krishna Nirde; Prashant S. Mulay; Uttam M. Chaskar
> **Conference** - 2017 International Conference on Intelligent Computing and Control Systems (ICICCS)
> **Year** - 2017

The paper proposed a wireless solid waste management system for smart cities which allows municipal corporations to monitor the status of dustbins remotely over web servers and keep cities clean very efficiently by optimizing cost and time required for it. As soon as the dustbin has reached its maximum level, the waste management department gets an alert via SMS via a gsm module placed at the dustbin so the department can send a waste collector vehicle to respective location to collect garbage.

Sensor Selection
PIC Microcontroller
Force sensor
Ultrasonic sensor
GSM

Hardware setup
All the sensors are attached to the PIC microcontroller and ready to install on a regular dustbin.

Software/technologies used
Radio Frequency for transmission and receiving.

Cloud analytics/processes
Arduino modem and web server facilitate this.

Use cases
Use on existing bins in homes

2.7. IoT based solid waste management system for smart city

> **Author** - Ujwala Ravale; Anindita Khade; Namrata Patel; Suvarna Chaure
> **Conference** - 2017 International Conference on Current Trends in Computer, Electrical, Electronics and Communication (CTCEEC)
> **Year** - 2017

The objective of the paper is to enhance the practicality of IoT based solid waste collection and management system for smart cities. The project prevents overflowing around the road side and localities as smart bins are used in real time.

Sensor Selection
Arduino uno
R-pi
Ir sensor

Hardware setup
The IR sensors are set up inside the dustbin with the arduino inside. It connects with the RPI server and sends data to the control unit.

Software/technologies used
Java, SQL

Cloud analytics/processes
Local server based project and does processing using Java Language.

Use cases
Can be used in homes and wherever the installation is possible on a bin.

2.8. Cloud-based smart waste management for smart cities

> **Author** - Mohammad Aazam, Marc St-Hilaire, Chung-Horng Lung, Ioannis Lambadaris
> **Conference** - 2016 IEEE 21st International Workshop on Computer Aided Modelling and Design of Communication Links and Networks (CAMAD)

Year - 2016

They propose a cloud-based smart waste management mechanism in which the waste bins are equipped with sensors, capable of notifying their waste level status and upload the status to the cloud. The stakeholders are able to access the desired data from the cloud.

Sensor Selection
Ultrasonic Sensor
Router
esp8266

Hardware setup
The sensor is connected inside the bin and sends the data through a router to the cloud

Software/technologies used
CloudSWAM

Cloud analytics/processes
The project talks about using Route analysis and finding an optimal route for the garbage picker and also big data analysis and processing for the data received from all the bins in the city

Use cases
The perfect use case for this system would be for a whole city along with the municipal corporation of that city and a central cloud.

2.9. Smart solid waste management

Author - Ravi Kishore Kodali; Venkata Sundeep Kumar Gorantla
Conference - 2017 3rd International Conference on Applied and Theoretical Computing and Communication Technology (iCATccT)
Year - 2017

This paper talks about and focuses more on classifying the the waste and dealing with each category of waste separately

Sensor Selection
Ultrasonic sensor

Moisture sensor
GPRS/GPS
RFID
Motion detection

Hardware setup
Doesn't talk much about in detail

Software/technologies used
Just talks about how these sensor data could help make the process efficient with no detail of softwares used

Cloud analytics/processes
Just talks about how these sensor data could help make the process efficient with no detail of analytics or processes

Use cases
Could be implemented on traditional bins

2.10. IoT based waste management: An application to smart city

> **Author** - B.S. Malapur; Vani R. Pattanshetti
> **Conference** - 2017 International Conference on Energy, Communication, Data Analytics and Soft Computing (ICECDS)
> **Year** - 2017

In this paper, proposed IoT technologies with management of waste and trip management in cities are done, so that cost and time are reduced with an optimized path for waste collection. Thus proposed effective results for the same.

Sensor Selection
Ultrasonic sensor
Arduino

Hardware setup
Ultrasonic sensor and Arduino connected to a traditional bin

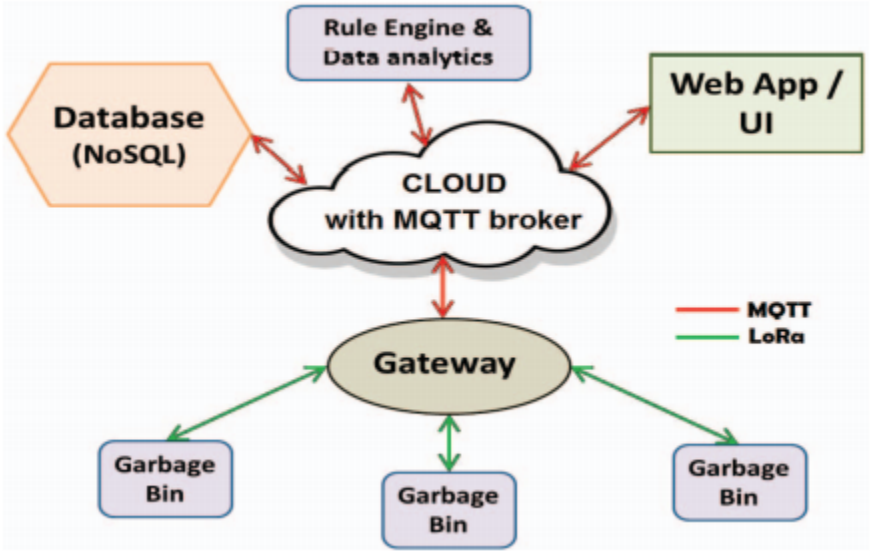
Software/technologies used
The paper uses the RF technology to transmit and receive data

Software : Mysql and netbeans

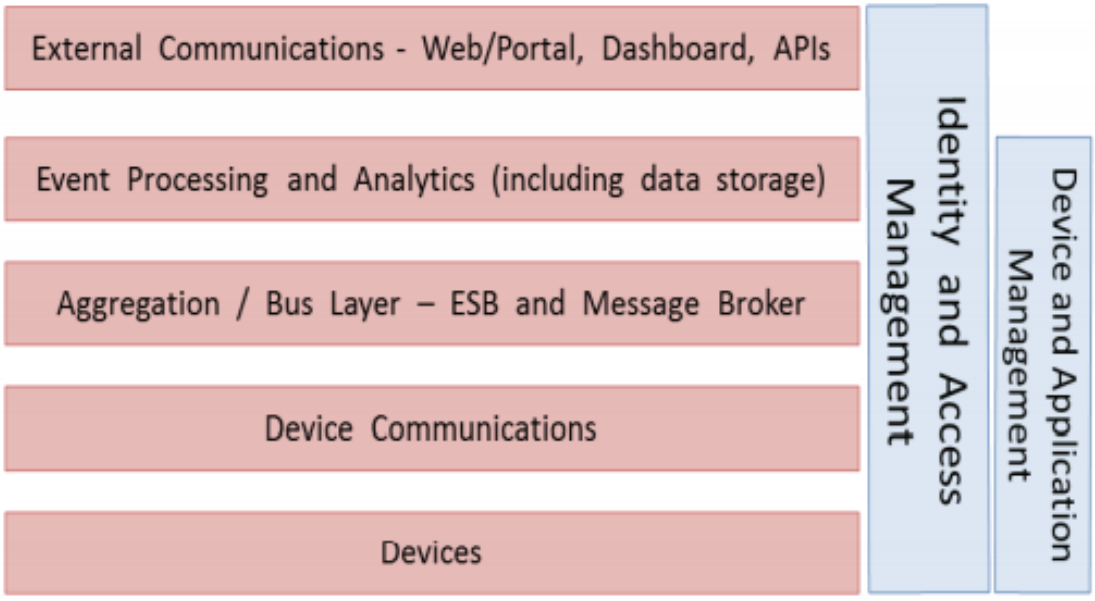
Cloud analytics/processes
Receiver is connected to the cloud and database where processing takes place and data is stored in a cloud database

Use cases
Any smart household can use this system with their existing bins.

3. Proposed System Model



Proposed Architecture of Solid Waste Management System



Block Level Architecture

4. Results and Discussions

4.1. Algorithms that can be used to overcome the issues

1. Internet of things-based urban waste management system for smart cities using a Cuckoo Search Algorithm
2. Enhanced Route Selection (ERS) algorithm for IoT enabled smart waste management system
3. A Waste Management Technique to detect and separate Non-Biodegradable Waste using Machine Learning and YOLO algorithm

4.2. Analysis of the algorithms

4.2.1. Cuckoo Search Algorithm:

Being a non-linear algorithm, as the name suggests it is based on aggressive brooding parasitism of some cuckoo species and their egg laying strategy. In real life environments cuckoos lay their eggs in the nests of other host species. To make sure the host species doesn't discard the egg for being too 'alien', many cuckoo species have adapted to creating a near identical replica of the host's eggs.

Cuckoo search algorithm therefore idealizes such breeding behavior, and thus can be applied for various optimization problems. It has been shown that cuckoo search is a special case of the well-known (μ + λ)-evolution strategy.

General pseudocode for a CS Algorithm is:

```
Objective function: f(x),   x = (x_1, x_2, ..., x_d);
Generate an initial population of n host nests;
While (t<MaxGeneration) or (stop criterion)
   Get a cuckoo randomly (say, i) and replace its solution by performing Lévy flights;
   Evaluate its quality/fitness F_i
         [For maximization, F_i ∝ f(x_i) ];
   Choose a nest among n (say, j) randomly;
   if (F_i > F_j),
          Replace j by the new solution;
   end if
   A fraction (p_a) of the worse nests are abandoned and new ones are built;
   Keep the best solutions/nests;
   Rank the solutions/nests and find the current best;
   Pass the current best solutions to the next generation;
end while
```

When it comes to the application in our particular topic, an intelligent waste management system that uses a deep convolutional neural network to reduce manual waste management and to clean the city in the minimum amount of time can be proposed to help with solid waste management.

An IoT sensor can be placed on the bins to collect waste-related information, which would then be processed by a layered optimization algorithm that classifies the waste. This is where the CS algorithm comes into play.

It is clear that waste management plays a crucial role in smart cities; thus, optimized machine learning techniques need to be applied to IoT-based waste data collection. Even though these intelligent approaches are effective at waste recognition, they have low predictive accuracy, which reduces the efficiency of the entire waste management and recycling process. Thus, study indicates that applying Cuckoo Search Optimized Long Short Term Neural Networks (CLSTRNN) to the analysis of IoT-based waste data can help. The main contribution of this algorithm is:

- Maximization of waste material classification accuracy
- Reduction of bin overflows and improvements in truck size prediction.
- Reduction of errors in waste material and bin overflow analyses.

4.2.2. Enhanced Route Selection Algorithm:

A major problem when it comes to smart waste management enabled by IOT is the issue of Data transmission Delay. Data transmission delay is one of the biggest challenges in wireless sensor networks.

An algorithm whose performance gives credence to be useful when it comes to this situation and can be applied to smart waste management is the Enhanced Route Selection algorithm.

This algorithm's biggest strength is bringing forth an efficient routing technique.

This will overcome data communication delay by considering one of the vital QoS parameter end-to-end delay.

- This proposed method takes into account the length of the routing path, link reliability, hop count in the path and energy availability.
- This proposed architecture can also be simulated in NS3 Tool.
- This proposed method outperforms existing methods in this related field with respect to the optimization of End-to-Delay, average remaining energy and average energy consumption.

4.2.3. YOLO Algorithm

YOLO is an algorithm that utilises neural networks to provide real-time object detection. This algorithm is popular because of its speed and accuracy.
It is an abbreviation for the term 'You Only Look Once' and therefore can be defined as an algorithm that detects and recognizes various objects in a picture (in real-time). Object detection in YOLO is done as a regression problem and class probabilities are provided of the detected images.

YOLO algorithm employs convolutional neural networks (CNN) to detect objects in real-time. As the name suggests, the algorithm requires only a single forward propagation through a neural network to detect objects. This means that prediction in the entire image is done in a single algorithm run. The CNN is used to predict various class probabilities and bounding boxes simultaneously.

YOLO algorithm works using the following three techniques:

- Residual Blocks
- Bounding Box regression

- Intersection Over Union (IOU)

Considering the object detection capabilities of YOLO algorithm, it with the usage of Machine Learning will prove beneficial when it comes to object detection, specially when it comes to the application of identifying non biodegradable waste from biodegradable waste which goes a long way in helping with proper waste management as distinction between the two is crucial and YOLO algorithm proves useful in its application towards that end.

5. Conclusion

From the detailed literature review, we come to a conclusion that there are alot of solutions available for the current need however they mostly take into consideration the quantity of the bins and do not actually provide a detailed process to classify the waste into different categories. Mostly all the proposed systems are using ultrasonic sensors to detect the level of waste and providing a route to optimise the collection of garbage with proper detailed documentation on how to achieve the same but the ones talking about segregating the waste are not discussing the technology and the processing involved clearly. We have a wide range of solution ranging from personal use case, to a city based used case providing multiple features and using different technologies and approaches may it be the programming language or an algorithm or the choice of sensors used , the choice of papers chosen for this review covers all aspects of the problem of “Solid Waste disposal” however some papers do lack proper documentation. There have been a lot of papers in this field in the period of 2015-2020 and on a holistic level, we feel they cover the topic quite well except proper documentation on the automated segregation of waste techniques. With this statement, we would like to conclude our report.

6. References

7.1. S. S. Chaudhari and V. Y. Bhole, "Solid Waste Collection as a Service using IoT-Solution for Smart Cities," 2018 International Conference on Smart City and Emerging Technology (ICSCET), 2018, pp. 1-5, doi: 10.1109/ICSCET.2018.8537326.

7.2. S. Ravi and T. Jawahar, "Smart city solid waste management leveraging semantic based collaboration," 2017 International Conference on Computational Intelligence in Data Science(ICCIDS), 2017, pp. 1-4, doi: 10.1109/ICCIDS.2017.8272627.

7.3. T. S. Vasagade, S. S. Tamboli and A. D. Shinde, "Dynamic solid waste collection and management system based on sensors, elevator and GSM," 2017 International Conference on Inventive Communication and Computational Technologies (ICICCT), 2017, pp. 263-267, doi: 10.1109/ICICCT.2017.7975200.

7.4. A. Jain and R. Bagherwal, "Design and implementation of a smart solid waste monitoring and collection system based on Internet of Things," 2017 8th International Conference on Computing, Communication and Networking Technologies (ICCCNT), 2017, pp. 1-5, doi: 10.1109/ICCCNT.2017.8204165

7.5. F. R. Maulana, T. A. S. Widyanto, Y. Pratama and K. Mutijarsa, "Design and Development of Smart Trash Bin Prototype for Municipal Solid Waste Management," 2018 International Conference on ICT for Smart Society (ICISS), 2018, pp. 1-6, doi: 10.1109/ICTSS.2018.8550013

7.6. K. Nirde, P. S. Mulay and U. M. Chaskar, "IoT based solid waste management system for smart city," 2017 International Conference on Intelligent Computing and Control Systems (ICICCS), 2017, pp. 666-669, doi: 10.1109/ICCONS.2017.8250546
7.7. K. Nirde, P. S. Mulay and U. M. Chaskar, "IoT based solid waste management system for smart city," 2017 International Conference on Intelligent Computing and Control Systems (ICICCS), 2017, pp. 666-669, doi: 10.1109/ICCONS.2017.8250546.

7.8. M. Aazam, M. St-Hilaire, C. Lung and I. Lambadaris, "Cloud-based smart waste management for smart cities," 2016 IEEE 21st International Workshop onComputer Aided Modelling and Design of Communication Links and Networks (CAMAD), 2016, pp. 188-193, doi: 10.1109/CAMAD.2016.7790356.

7.9. R. K. Kodali and V. S. K. Gorantla, "Smart solid waste management," 2017 3rd International Conference on Applied and Theoretical Computing and Communication Technology (iCATccT), 2017, pp. 200-204, doi: 10.1109/ICATCCT.2017.8389133.

7.10. B. S. Malapur and V. R. Pattanshetti, "IoT based waste management: An application to smart city," 2017 International Conference on Energy, Communication, Data Analytics and Soft Computing (ICECDS), 2017, pp. 2476-2486, doi: 10.1109/ICECDS.2017.8389897