Smart Waste Management Systems for Sustainable Urban Life Based on IoT for Scalable IoT-Based Smart City Solutions

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Declaration

It is hereby declared that

1. The thesis submitted is our own original work while completing the degree at Brac University.
2. The thesis does not contain material previously published or written by a third party, except where this is appropriately cited through full and accurate referencing.
3. The thesis does not contain material that has been accepted or submitted, for any other degree or diploma at a university or other institution.
4. We have acknowledged all main sources of help.

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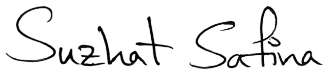

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Approval

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Ethics Statement (Optional)

You are performing a meta-analysis to see if working from home is associated with improved stress management. You collect all relevant research on the issue that meets your search parameters. You observe that two published research from separate years share comparable characteristics. Their sample sizes, locations, treatments, and outcomes are quite comparable, and they have a common author.

Abstract

In smart cities, the volume of data collected by IoT-based sensors is rapidly increasing. These devices are networked and provide information about how humans utilize them together and independently, as well as how they could be improved. Every individual and business generates waste, but its disposal must be controlled to prevent dangers to public health and the environment. In order to develop sustainable and habitable cities, efficient waste management systems must be implemented. In this situation, recycling is an effective waste management strategy that can be adopted. To ensure the effectiveness of a recycling program, cities and communities must make waste management services easily available. Waste management entails the collection, transportation, and disposal of sewage, rubbish, and other types of waste. Some have postulated that a cognitive network of the fifth generation could contribute greatly to the overall enhancement of IoT system functionality. Today, solid waste is one of the most pressing issues on a global scale, as poor rubbish disposal from villages, towns, and cities has a negative impact on the local population and is the root cause of new diseases. Consequently, technologically-advanced trash management is a pressing matter. In the existing traditional system, garbage monitoring and disposal are performed by humans, which is cumbersome; thus, by incorporating IoT into the traditional system, garbage bin monitoring will be simplified. In this study, we investigate the Internet of Things and propose an IoT-based architecture for a Smart Waste Management System in a smart city. Our purpose is to demonstrate how IoT may be utilized to handle and manage smart city waste while accounting for scale and adaptability challenges. The suggested system employs ultrasonic sensors to detect the level of trash in the bin and communicate the status of the waste to the bin. Using global system for mobile (GSM), the server will notify the appropriate individuals (driver of garbage collection vehicle) via SMS and GPS location. The driver will gather waste and update the server accordingly. The proposed trash management system is vastly superior to the waste management systems currently employed in its industry since it employs significantly less workers to fulfill its goals, prevents rubbish spills, reduces processing times and costs, and is entirely automated. Our suggested model can accurately track the status of garbage containers with a 91% success rate, while waste disposal accuracy is 89%. In addition, we investigate the vast array of potential technical applications in a "smart city," including "smart houses," "smart buildings," "smart industries," etc.

Keywords: IoT, Smart City, 5G, Garbage Management System

Dedication (Optional)

This project is dedicated to our parents, who have never failed to provide us with financial and spiritual support, for meeting all of our needs during the time we were developing our system, and for showing us that even the most daunting tasks can be completed if they are approached methodically. This project is also dedicated to the instructors that assisted and directed us through the completion of this project.

Acknowledgement

Firstly, all praise to the Great Allah for whom our thesis have been completed without any major interruption.

Secondly, this paper and the research behind it would not have been possible without the exceptional support of our supervisor Mr. Amitabha Chakrabarty, PhD and Co-advisor Mr. Md. Golam Rabiul Alam, PhD sir for their kind support and advice in our work. They helped us whenever we needed help.

And finally to our parents without their throughout support it may not be possible. With their kind support and prayer we are now on the verge of our graduation.

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Nomenclature

The next list describes several symbols & abbreviation that will be later used within the body of the document

$5G$ Fifth Generation

GPS Global Positioning System

GSM Global System for Mobile Communication

$HTTP$ Hyper Text Transfer Protocol

IoT Internet of things

$M2M$ Machine to Machine

$MIMO$ Multiple Input Multiple Output

URL Uniform Resource Locator

Chapter 1

Introduction

The objective of this paper is to introduce a waste management system in order to maintain a clean environment. Waste management consists of garbage collection, transportation, processing, recycling, and disposal. Effective waste management systems incorporate advanced management strategies to mitigate environmental risks and conserve resources. This chapter will explain briefly why we are working on this project, the problem description, and our research objectives.

1.1 Background

Hygiene, crime, traffic, tax collection, management of public utilities, and emergency services are all issues that have plagued city residents for approximately 6,000 years when they first began settling in cities. Electrical grid; telephone and cellular networks; internet (including fiber optic and cable networks); hot and cold running water; water and waste treatment; garbage and recycling collection; public parks and recreation facilities; rail, light rail, and automotive streets, roads, thoroughfares, and rights-of-way are required for the successful implementation of technological advances. Modern ”smarter” cities are able to improve the speed and quality of service delivery through ongoing monitoring of residents and infrastructure and near-immediate reporting of unsatisfactory performance. This requires extensive automation, Internet connectivity, and the so-called ”Internet of Things (IoT)” ”Smart Municipal” initiatives must be implemented to enhance the quality of life for urban dwellers. Nevertheless, smart city applications such as healthcare, smart transportation, the retail industry, and firefighting generate a significant amount of data. How to effectively manage huge amounts of data in the context of ongoing operations is a subject of ongoing discussion. The Machine-to-Machine (M2M) and cooperative contact allowed by the Cognitive Radio Network (CRN) is crucial to the 5G Internet of Things (IoT). Fifth-generation (5G) networks will have difficulty distributing resources due to the increasingly complicated communications system structure and the expanding traffic load across wireless communication systems, both of which cannot be met by cognitive radio (CR) technology. This is because 5G networks can sustain significantly more data traffic than their predecessors. This section explains why and how cognitive radio networks can be utilized to govern the inherent structural and operational boundaries that smart habitats require of a 5G wireless/mobile network. Cognitive radio is the solution to this challenge, which is created by the growth of wireless technologies such as mobile phones and other wireless services, which has increased the need for spectrum capacity. A component of this is the utilization of a cognitive cycle consisting of observation, orientation, strategy, production, action, and comprehension of past events. SDR, or software-defined radio, enables the modification of multiple variables (modulation, frequency, etc.).

The CRN's capacity to distinguish network states [21] and to apply previously acquired knowledge at various stages throughout the learning process is an added advantage. The Internet of Things is currently being used in metropolitan areas. It is anticipated that the Internet of Things will increase the intelligence of cities by allowing connections between individuals and their surroundings. These systems incorporate a wide range of Internet of Things (IoT) technologies and transmission methods (such as wireless sensor networks, radio frequency identification, camera systems, intelligent scaling [18], actuators, broadband services, and accessible data set outlets) and are designed to serve a variety of purposes [22].

The proper disposal of waste has emerged as an issue of international importance. Garbage is often produced by households, businesses, building sites, refineries, and nuclear power stations. Consumption habits are changing as the world's population rises. The environmental risks have grown in tandem with the human population. The health and safety of humans and other living things is at danger if trash is not properly handled. All aspects of garbage, from collection to disposal to treatment and recycling, are within the purview of waste management. [12] In the past, people would get rid of their garbage by digging a hole in a remote part of the property. This was the traditional method. This method of garbage disposal was developed to be as effective as possible because there was a significantly smaller population at the time. Because there were fewer people, there was less garbage produced, which made waste management much simpler. In recent years, on the other hand, due to a rise in population, the output of waste has exploded, making it difficult to dispose of.

Garbage in today's world is typically made up of inorganic and non-biodegradable materials. If this material is thrown away in landfills, the process of its disintegration will be drawn out and not in accordance with nature. Customers are able to dispose of any and all types of rubbish in a manner that is both effective and efficient thanks to garbage management. Because of the current circumstances, standard procedures for waste management cannot be utilized. The methods for managing trash have evolved over time, and it is critical that we comprehend the significance of waste management to the creation of a sustainable future and the various ways in which we may contribute to the advancement of research and practice in this area. In contrast, applications for smart cities, such as healthcare, smart transportation, retail, and law enforcement, create vast quantities of data. Smart cities are sometimes referred to as connected cities. A continuing source of concern is how the enormous amounts of data that are being produced may be managed in the most effective and efficient manner possible. The use of cognitive computing to analyze vast amounts of data has been the subject of previous studies; however, these studies have not addressed a number of fundamental difficulties, such as the scalability and flexibility of data obtained in the context of smart cities. It is possible that the data gathered from millions of sensors might be dispersed across numerous cognitive computing applications in order to deliver replies in real-time. This research looks into the Internet of Things and proposes an Internet of Things–based smart city architectural system that might be used for a smart waste management system. Our goal is to demonstrate how the Internet of Things (IoT) may be used to manage and handle garbage in smart cities while simultaneously addressing challenges of scalability and flexibility. In addition to this, we will go through some other concepts for smart cities.

1.2 Problem Statement

An unprecedented 2.12 billion tons of garbage are produced annually by our species. If all of this garbage was loaded into trucks and driven across the planet, it would take twenty-four trips around the globe. There is little evidence to suggest that the rate at which global waste production has been rising over the past few decades has slowed down. It is anticipated that by the year 2050, the amount of municipal solid waste produced around the globe would have increased by nearly 70 percent, reaching 3.4 billion metric tons. This phenomenon is the result of the interplay of a number of factors, including the rise in population, the process of urbanization, the expansion of the economy, and the shopping preferences of consumers. Every year, people generate millions of tons of waste, which is becoming an increasingly pressing problem across the globe. As the amount of waste produced has increased, there has been a corresponding increase in the requirement for the authorities to offer appropriate services for the treatment and disposal of the rubbish. On the other hand, less than 20% of waste gets recycled each year, which means that enormous quantities continue to be dumped in landfills. [2]
Interactions between IoT, 5G, and other wireless networks are important for the development of a paradigm capable of supporting all Internet of Things applications. Frost Sullivan predicts that IoT will transition from traditional computing to cognitive and predictive computing within the next 12 to 18 months. The Internet of Things (IoT) will likely undergo a stratospheric rise in popularity in the near future, according to the study results. From now until 2023, it is anticipated that the compound annual growth rate (CAGR) for the entire world would be 20.3%. This is an increase from the 12.4 billion IoT devices in use in 2016 to the anticipated 45.3 billion devices in use in 2023. The Internet of Things (IoT) and telecommunications are essential components for the building of smart infrastructure in urban development. This infrastructure is required for the management of the metropolitan population's continued growth. To be deemed a smart city, mobility, communication, safety measures, and infrastructure development must all be on the cutting edge of technology. Internet of Things (IoT) devices and solutions are being included in architectural designs by construction companies in order to produce infrastructure that is not only cost-effective but also of high quality and self-sustaining. Integration of Internet of Things (IoT) technologies into the development of smart cities is a top goal for both developed and developing nations seeking public-private collaborations (PPP) [25]. Consequently, research is being conducted to address the following question:
How can we construct a smart waste management system alongside a 5G-enabled smart city, merge with 5G networks to boost 5G and IoT efficiency, and develop a common model for a smart city? The Internet of Things (IoT) will be created to serve as a stand-alone model for a smart garbage management system in a 5Genabled smart city. A new model will be combined with 5G to improve the network and increase 5G efficiency. To answer the topic, the study will examine IoT, smart

cities, waste management systems, etc

1.3 Research Objectives

The creation of a practical waste management city model for the smart city is the main objective. IoT and 5G network integration will be used to enhance the model. It is now possible for everything, from intelligent sensors to self-driving cars, to connect at incredibly fast rates with very little latency, which makes a smart city. Also, some other concepts from the different areas will be discussed to improve the model.

Systems and resources more effective, Cognitive radio network (CRN) techniques in wireless systems could person realize the sensual Internet [26], a lengthy data network, and intelligent upcoming networks. Not only the city but also environmental balance has been taken into account to preserve environmental safety. So, the main objective of this paper is:

- To create an intelligent model of a waste management system suitable for use in a 5G-enabled smart city.
- Conduct an analysis of the model's usability as well as its ability to be maintained.
- ln order to gain an understanding of how the Cognitive Internet of Things can be incorporated into the smart city.
- To provide an additional model in order to enhance life in smart cities.

1.4 Document Outline

This report contains five chapters. Chapter 1 briefly describes the research problem, its explanation, and our proposed solution. The relevant literature and related studies are reviewed in Chapter 2. This section contains a comprehensive explanation of our paper's relevant topics. In addition, it provides previous work relevant to our paper. It contains an expanded explanation of cognitive IoT, smart cities, and waste management systems, among others. In the third and last chapter of our study, we propose our model. It contains the suggested model of the problem we are attempting to solve. From the E-bin to the waste disposal phase, the operation of our model is described below. We constructed our model using hardware such as Arduino, sensors, GPS, GSM, etc. Also discussed is our self-made system. In Chapter 4, we analyze the results and assess the performance of our suggested model. We have compared system performance with directly collected raw data. In the conclusion and future work section of Chapter 5, we provide an overview of the study. In addition, potential future developments and extensions of this paradigm are mentioned below.

Chapter 2

Literature Review and Related Works

This chapter will examine CRNs, CIoT, 5G networks, and the dependence of CRNs on 5G networks. The objective of this chapter is to provide an overview of these topics. A concise introduction of smart city applications will also be provided, and we will examine several algorithms, such as A* Search, Haversine algorithms, and Cuckoo search, all of which will work together to assist us in developing our proposed algorithms. This chapter also offers information on the notion of smart cities as well as publications that are linked to our paper.

2.1 Background Studies

2.1.1 Cognitive Radio Networks (CRNs):

The proliferation of wireless technology is hastening in response to the ”spectrum scarcity” that has been identified. CRNs are widely regarded as one of the most effective and potentially game-changing communication technologies for addressing ”spectrum scarcity” concerns, particularly in light of the impending deployment of 5G communication systems and beyond. [20] Joseph Mitola came up with the term ”cognitive radio” (CR) in 1999-2000 so that it could be used to describe intelligent radios that are capable of drawing their own conclusions based on the information they have received about the RF (radio frequency) environment and that rely on their prior experiences to learn and plan. The network structure of CRNs that are spread hierarchically is displayed in Figure 1. According to Simon Haykin, CR is an autonomous wireless communication system that has the capacity to be conscious of its surroundings, analyze them, and modify its operational settings in real-time in order to facilitate smooth connectivity and effective utilization of radio spectrum. CR can do all of these things because it has the ability to be self-aware. [9]. In order to increase the capabilities of radio links all the way up to the network layer, CRs will build a CRN. In CRNs, heterogeneous networks are formed by the combination of a wide variety of networks and communication technologies. CRNs have application across a wide range of architectural frameworks, including network-centric, distributed ad-hoc, and many more. [9]. The cognitive cycle is a series of actions carried out by the cognitive engine in order to satisfy a set of requirements. This cycle is a defining characteristic of CR technology. The CR cycle was initially proposed by Mitola [5]. The cycle starts out with the first stage, which is sensing. In order to attain this goal, vital information regarding the electromagnetic activity brought on by various radio broadcasts over a variety of spectrum bands will need to be gathered. A CR was required to make decisions about the band selection in real time in order to get a sense of how time duration affects energy conservation. In the second stage of the procedure, which is referred to as the ”spectrum analysis,” prospective spectral possibilities, also known as ”spectrum gaps,” in the surrounding radio environment are located and analyzed. In the third stage, the operational parameters are decoded utilizing the findings of the analysis completed in the previous phase. In the fourth stage, the set of transmission elements that require modification is finished [8]. One of these networks is the primary network, and the other is the secondary network. The major network, which includes the primary radio base station and users, is the owner of the licensed band. Figure 2.1 presents the comprehensive outline of the CR infrastructure's architectural design.

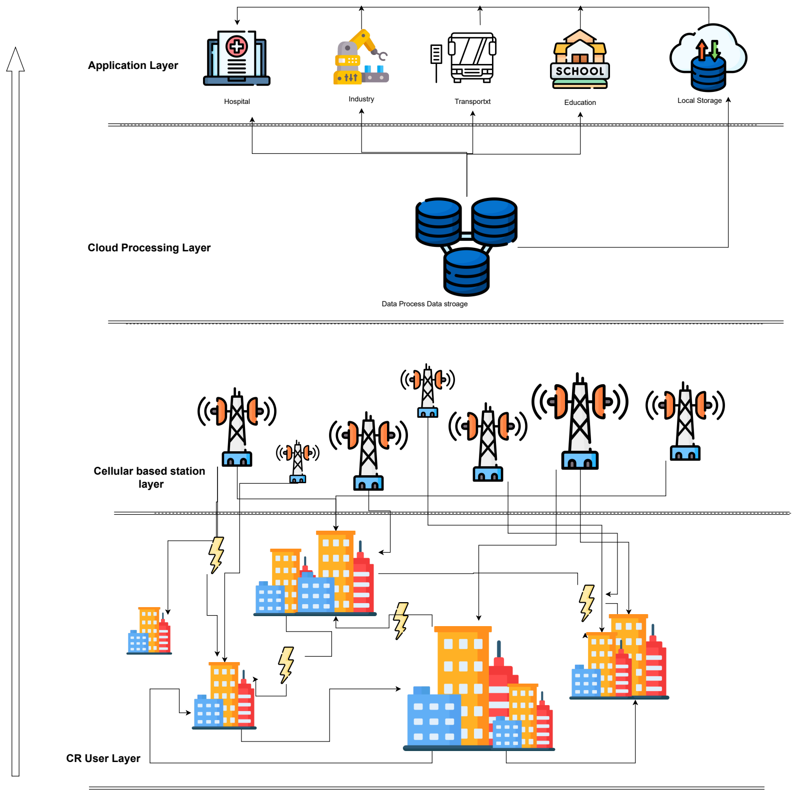


Figure 2.1: Hierarchical distribution of CR infrastructure

The unused spectrum is shared between both networks. The cognitive radio base station and users make up this system. The following are the three fundamental capabilities that distinguish cognitive radio from regular radio Cognition: CR is aware of its geographic and operational surroundings. Reconfiguration: CR can opt to modify its parameters dynamically and autonomously based on this cognitive understanding. Learning: CR can benefit from the experience by experimenting with different configurations in different situations.
Cognition: CR is aware of its geographic and operational surroundings. **Reconfiguration:** CR can opt to modify its parameters dynamically and autonomously based on this cognitive understanding. **Learning:** CR can benefit from the experience by experimenting with different configurations in different situations.

2.1.2 Cognitive Internet of Things (CIoT):

The Internet of Things (IoT) is a hybrid network of physical things, or "things," that are outfitted with sensors, software, and other advances to allow communication and data sharing with other systems and devices over the internet. CNs are a fundamental component of the IoT and will be used in a variety of applications on the future internet, including environmental monitoring, agricultural, and medical research. As a result, a potential substitute for IoT applications is the cognitive radio-based Internet of Things (CIoT), which leverages cognitive technology [15]. The Internet of Things (CIoT) appears to be a new network principle in which things are interconnected and act as agents with less human interaction; the objects communicate using a context-aware perception-action cycle; they learn from physical circumstances and social networks using the understanding by-building approach; they store the acquired conceptual and/or knowledge in various records; and the objects adapt to their environment to become better. The CIoT is described as the combination of existing IoT with intellectual and altruistic mechanisms to improve overall functioning and intelligence [8]. In Figure 2.2 the CIoT architecture is shown with all the components and operational systems.

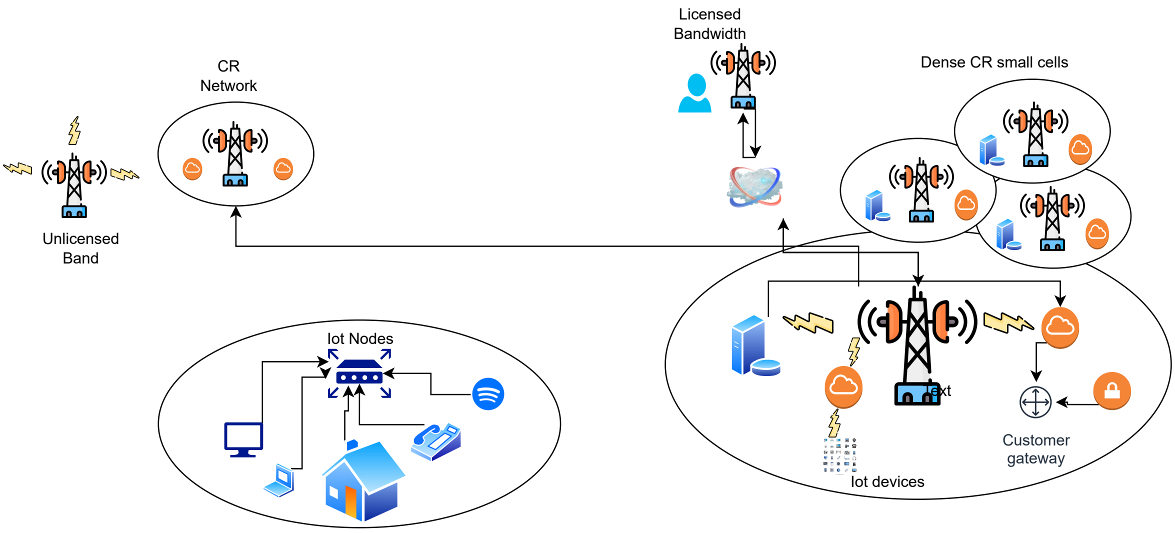


Figure 2.2: Cognitive IoT (CIoT) architecture.

Objects with communication capabilities, such as those available on IoT or Machine To-Machine (M2M), etc., as well as their devices, are anticipated to be able to see, think about, and comprehend the physical and virtual settings in which they are expected to operate. As a result, they will be outfitted with CR capabilities. IoT devices today come with five critical cognitive functions. Semantic derivation, knowledge discovery, intelligent decision-making, perception-action cycles, huge data processing, and on-demand service provisioning are all conceivable in accordance with the CIoT concept [8].

2.1.3 5G and CRNs based 5G network

It is anticipated that 5G would usher in a transformation that goes beyond speedier browsing and improved telephony. The initial step in maximizing 5G's potential is to appreciate its capabilities. It is anticipated that a cognitive 5G network will be

essential for boosting the performance of an IoT framework. It is anticipated that the IoT systems of the cognitive 5G network would enable the flexible delivery of a wide variety of services as well as steady operations in highly dynamic environments. It is anticipated that a cognitive 5G network will be essential for boosting the performance of an IoT framework. The IoT systems of the cognitive 5G network are expected to enable flexible delivery of a wide variety of services as well as stable operation in highly dynamic environments. The Cognitive 5G architecture for IoT is depicted in Figure 2.3 with a full structure and Cognitive Radio Networks.
All four previous generations of mobile networks relied on macro cell towers hundreds of feet tall to transmit data over vast distances. 5G operates uniquely. This augmented mobile network increases throughput by combining frequencies from several bands. 5G will use many, substantially smaller microcells for the new millimeter wave spectrum bands in addition to regular macro cell towers to enable ultrahigh-speed network coverage. CRNs are viewed as a feasible solution for future 5G applications on account of the dynamic spectrum access technology they employ. CRN's primary objective is spectrum sharing, which helps address the problem of spectrum shortage [27].

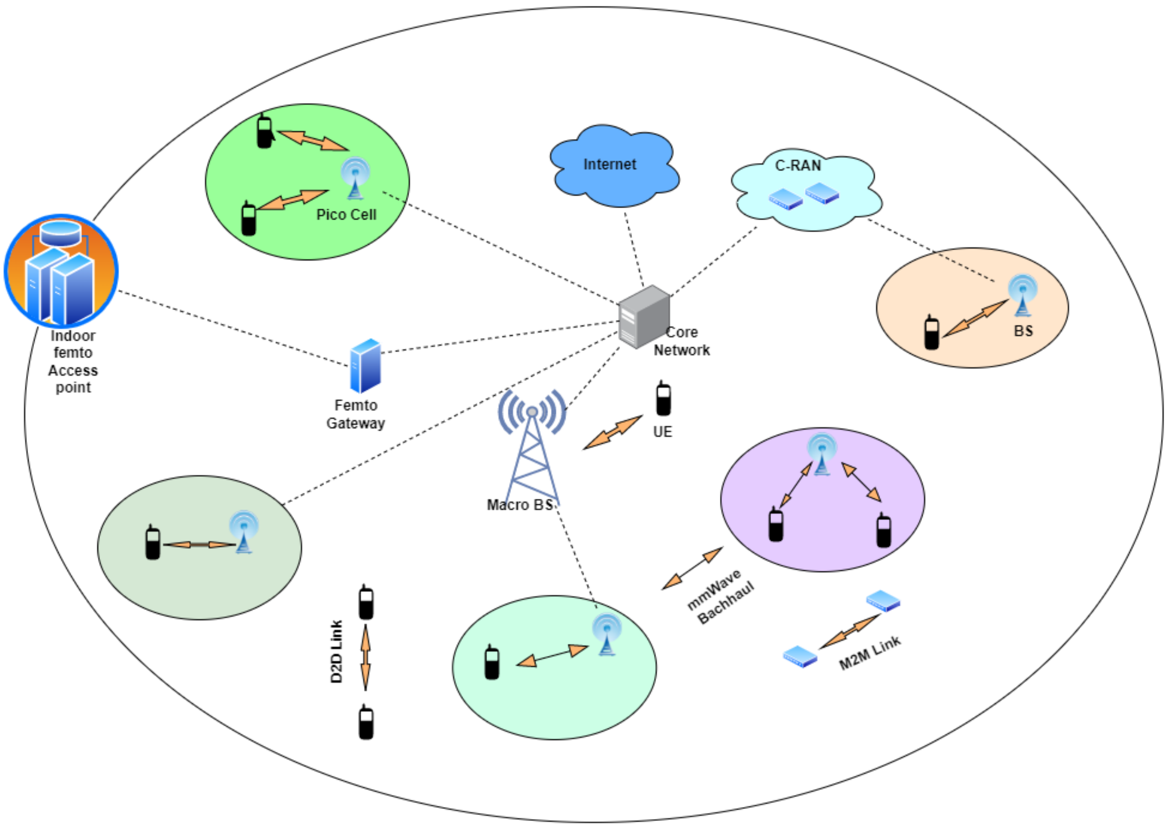


Figure 2.3: Cognitive 5G architecture for IoT

In CRNs, spectrum sharing (SA) can be described in two ways. Spectrum sharing (SA) is defined as either open-source or licensed sharing depending on which spectrum band the secondary users occupy. In the first scenario, each secondary user has equal access to the unlicensed ISM band. In the latter strategy, known as "hierarchical spectrum sharing" (SA) [9], the secondary user dynamically and opportunistically shares the licensed primary band. Edge computing and the Internet of Things are fundamental components of 5G from the beginning, making it the first wireless network created with more than simply phones in mind. 5G's enhanced mobile network capacity and decreased latency will enable new applications, such as 5G-enabled smart factories and cities and always-connected medical equipment.

2.1.4 Smart City

In smart cities, the volume of data collected by IoT-based sensors is rapidly increasing. These devices are interconnected and provide information on how humans use them together and separately, as well as how they might be adjusted to serve better. Traditional methods have failed to provide users with personalized, human-like solutions. The academic and corporate communities are interested in the combination of artificial intelligence (AI) and cognitive science. Cognitive computing is built on the process of teaching artificial intelligence to work with human-like cognitive capacities [23]. Utilizing IoT sensors such as headbands, wearables, and smartphones, it learns from people's psychology, environment, voice, and social media to provide human-like reasoning abilities. Watson, IBM's cognitive computing system, demonstrated the potential for machines to think like humans. Watson learns facts from documents without human input or supervision and communicates as though it were human using natural language processing. Watson was crowned winner on "Jeopardy!" without an Internet connection versus human competitors in 2011 [22]. Sub-layers of the smart city platform include smart buildings, residences, energy, transportation, agriculture, and industry, but are not restricted to these. In this setting, both organized and unstructured types of large data are produced. Smart homes and buildings collect sensor data on a variety of human characteristics, including emotions, voice, brain activity, etc. Future of IoT and future of our cities are interwoven. As city governments realize the full potential of urban data platforms, artificial intelligence, smart devices, and interconnectivity, the demand for the Internet of Things (IoT) will skyrocket. This will lead to problem-solving effectiveness, intelligent transportation, sustainability, and more [11]. One of the most intriguing ways the IoT could help future cities is by reducing the need for individual vehicles. With the advent of autonomous vehicles, it will not be long before IoT-enabled public transportation is accessible and efficient for everybody. Future autos and buses will be able to operate utilizing data provided by street furniture or lighting, leading in an efficient and seamless traffic flow.

2.1.5 Algorithms

A. A* Search

A* a searching algorithm is a searching algorithm that is optimal as long as complete too. It is a straightforward and efficient search strategy for determining the best route between two network nodes. It'll be utilized to discover the quickest path. It is an expansion of Dijkstra's shortest route algorithm. The A* Search Algorithm additionally employs a heuristic that offers extra information about how distant we are from the objective node. This function is used in combination with the f-heap data structure to improve search efficiency.

This function is used in combination with the f-heap data structure to improve search efficiency. For this algorithm, we can get the shortest path and we can get to the target cell as quickly as possible. In every step, we check a value F (the sum of 'g' and 'h') and process that node/cell. G: is the distance traveled from the initial point to a particular square on the grid by taking the route we created to get there. H: is the heuristic, which is an assessment of the distance from that square on the grid to the finish line. For the H value, we have used the actual distance from 2 points by using the Formula of the distance between two points. Which you can see: 2.1

$$d = \sqrt{(longitude_{user} - longitude_{worker})^2 + (latitude_{user} - latitude_{worker})^2} \quad (2.1)$$

For every node to every node we get a heuristic value by this formula 2.1. Heuristic value declaration is important because depending on the value our algorithm will be complete and optimal.

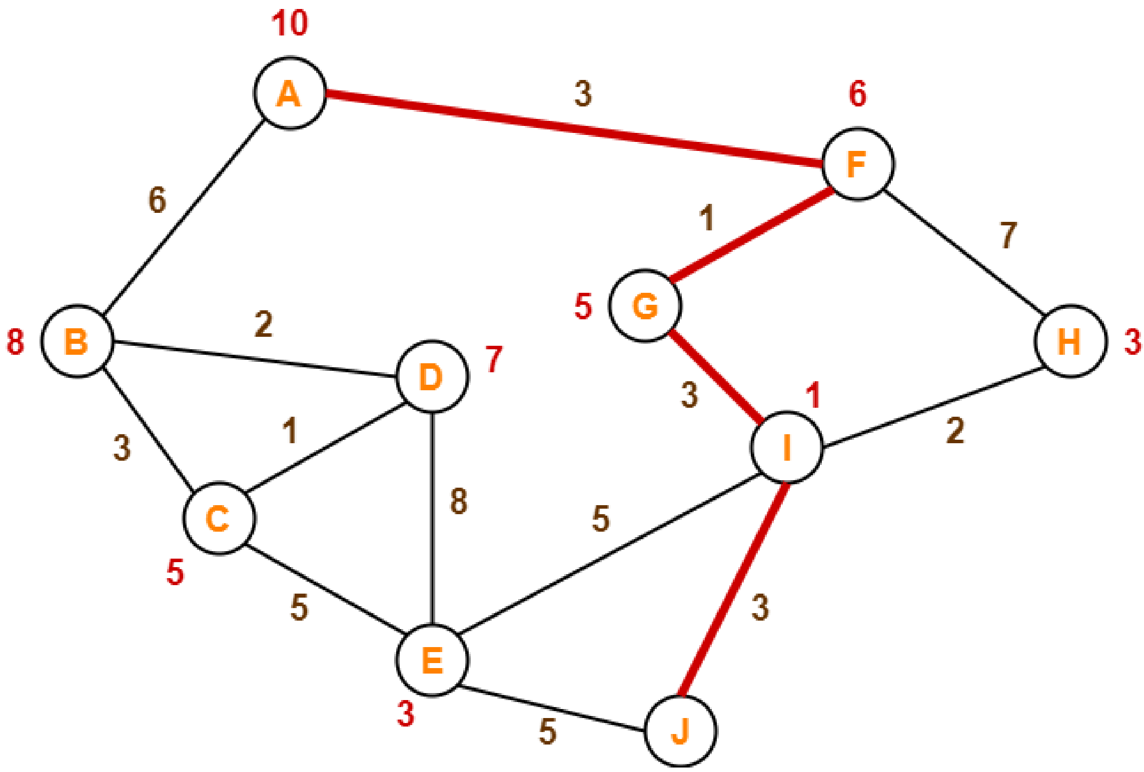


Figure 2.4: A* Search Algorithm

Conditions for being optimal:
A* search is optimum if the heuristic is acceptable. Admissibility ensures that whatever node you expand, the current prediction is always less than the ideal, ensuring that the path about to expand has a chance to locate the optimal path.
And our heuristic value from Formula 2.2 gives the distance between 2 points in a straight line which is the lowest possible distance between two points. A heuristic is consistent if, for every node n as well as every child n' of n created by any activity.

$$a, h(n) = c(n, a, n') + h(n') \quad (2.2)$$

If h is consistent, we obtain Formula 2.3

$$f(n') = g(n') + h(n') = g(n) + c(n, a, n') + h(n')g(n) + h(n) = f(n) \quad (2.3)$$

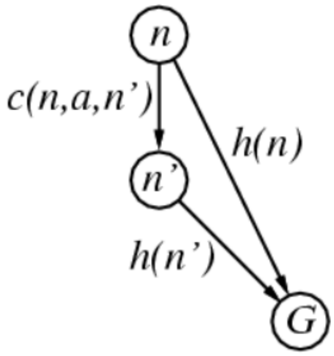


Figure 2.5: A* Search for optimal situation

B. Haversine Algorithm:

Given two places' longitudes and latitudes, the haversine formula calculates their great-circle separation. The law of haversines, which connects the sides and angles of hemispheric triangles, is a more broad formula in trigonometry that is significant in navigation. These names derive from the fact that they are conventionally defined in terms of a haversine function, given by Formula 2.4 2.5.

$$hav(\theta) = \sin^2 \frac{\theta}{2} \tag{2.4}$$

Formula:

$$Angle_{Central}(\theta) = \frac{d}{r} \tag{2.5}$$

d refers to the distance from two locations along the planet's orbit, whereas r is the diameter of the circle. This formula allows us to find the haversine angle (havθ) from the longitude(φ) and latitude(γ) among two points. The haversine formula is: 2.6

$$hav(\theta) = hav(\varphi 1 - \varphi 2) + \cos(\varphi 1).\cos(\varphi 2).hav(\gamma 1 - \gamma 2) \tag{2.6}$$

After completing this equation, we get the half varsine of the central angle using Formula 2.7. Applying the inverse haversine to

$$h = hav(\theta) \tag{2.7}$$

will result in the distance d from Formula 2.8 which is similar to 2.1

$$d = 2r \arcsin(\sqrt{h}) \tag{2.8}$$

$$d = 2r \arcsin(\sqrt{\sin^2 \frac{\varphi 1 - \varphi 2}{2} + \cos(\varphi 1).\cos(\varphi 2).\sin^2 \frac{\gamma 2 - \gamma 1}{2}}) \tag{2.9}$$

For this Formula 2.9, we must ensure the value of h is less than 1 because $\theta = \frac{d}{r} \leq 0.99999$

Law Of Haversines:

The third side's angular length is proportional to the product of the angular lengths of the initial and second sides, the angular displacement opposite the third side, as well as the sine of the first side. this can be found using Formula 2.10

$$hav(c) = \sin a. \sin b.hav(C) + \sin (a - b) \tag{2.10}$$

The lengths a, b, and c are easily calculated as the radians of the angles subtended by those sides with respect to the sphere's center of mass since this is a unit circle. Each of these arcs has a length equal to the product of its central angle and the sphere's radius R for a non-unit sphere. Figure 2.6 shows how Haversine Algorithm measures the distance.

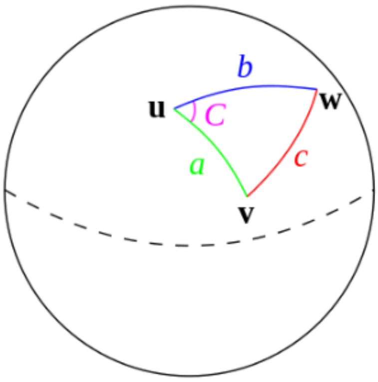


Figure 2.6: Haversine Algorithm

C. Cuckoo search algorithm:

The cuckoo search method is a way to find the nearest host that is based on optimization. Some species of cuckoo are obligate brood parasites, meaning that they must deposit their eggs in the nests of other species of birds in order to survive. Cuckoos may provoke aggressive behavior in certain host birds, and in some cases, the host birds will fight back. Figure 2.7 shows the flowchart of the Cuckoo Search Algorithm.

Each egg in the nest stands for a different answer, and the arrival of a cuckoo egg signals the arrival of a brand-new answer. The cuckoos are intended to replace an existing, less-than-optimal arrangement in the nests. A single egg is the bare minimum for a nest. Further complexity may be added to the method by having numerous eggs in each nest, each of which represents a different set of solutions.

By using this algorithm we can find the vehicle nearby. For this algorithm we need some steps to follow:

- Calculate Lavy's flight
- Calculate the step size.
- Calculate the cuckoo's new position.

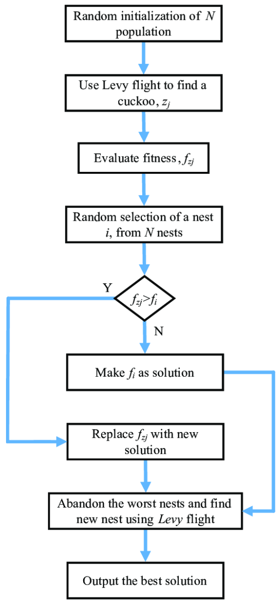


Figure 2.7: Cuckoo Search Algorithm

The simplicity of the algorithm is we only need two parameters one is the population of the nest which is our vehicle and the other on the probability of finding Cuckoo's egg which is our targeted bins.

Step 1:
Initialize the population of the nest (bin) = total number of bins in that area.
Step 2:
Initialize the worst case parameter (probability of finding the bin) / Pa = 0.25
Step 3:
Set parameter of the maximum time of iteration/ MaxT = 300.

Point to be noted that we cannot make any difference between the cuckoo/egg/nest.
The Aim of this algorithm is to find the bad solutions for the current nest position which is the vehicle and replace the solution with a better and new solution.

Step 4:
Obtain a new position for the ith cuckoo(vehicle) by Lavy's flight Lavy's flight performed as follows, assuming i = 1 at randomly

$$x_i^{t+1} == x_i^t + \alpha . \oplus .Lavy(\gamma) \tag{2.11}$$

$$x_i^{t+1} = New_{Solution} \tag{2.12}$$

$$x_i^t = Current_{Location} \tag{2.13}$$

$$\alpha = Step_{Size} \tag{2.14}$$

$$\oplus = Multiplication_{EntryWise} \tag{2.15}$$

$$Lavy(\gamma) = Lavy_{Exponent} \tag{2.16}$$

Random steps can be drawn from Lavy's distribution of large steps. We can find the step size by the Formula 2.17.

$$S = u * \frac{uvl}{2} \tag{2.17}$$

Here v is the normal stochastic value. By calculating step size we can make a decision like if s is too large our new location is too far from the old location and if s is small then our change of position is too small.

Step 5:

Select a random nest for the cuckoo and check again.

2.2 Related Works

This section will discuss previous significant work in the fields of CRNs, CIoT, and smart cities enabled with the 5G network. Smart buildings are now an increasingly important part of green infrastructure as IoT becomes more widespread. The Internet of Things (IoT) is a critical component as well as 5G for altering how cities connect and operate. These technologies release key infrastructure for the future of connected communities, thanks to IoT's limitless potential and 5G's tremendously high speeds and low latency. To put it simply, "smart cities" make use of technological innovations like 5G and IoT to design and offer connected solutions for a community's well-being. While 5G technical advancements alone will not accelerate the development of smart cities, the new 5G architecture substantially expands cities' ability to use smart devices, sensors, and data to enhance functions and processes.

The implementation of CR over the next 5G telecommunications [28] is the most significant advancement in global communications system bandwidth. However, new steps may be necessary to properly profit from IoT via cognitive 5G networks. In order to optimize IoT node connectivity for 5G, communication, and collaboration, it's also critical to look into resource allocation . The research study [7] examines CR network requirements and issues such as CRN cloud, portable cloud technologies, and network service remodeling, as well as an overview of the current CRNC study that will solve all remaining and 5G network elements and concerns. To address the restrictions, the author proposed a CR network virtualization authentication server implementation supporting network service sequences at the access point level. The CRN will meet the enormous demands of upcoming wireless or mobile networks; a 5G illustrated.

The research paper [24] described non-linear and non-wavelength sensing and power allocation policies for IoT in cognitive 5G technology. In a multiband strategy to optimize energy consumption for spectrum sensing, the author formulates an issue of optimization where each IoT node should be able to sense a minimum number of channels. The author then presented a spectrum-sharing architecture for CIoT, which includes multi-band spectrum access and resource allocation via cross-layer reconfiguration. In addition, in cognitive 5G networks, a CLRS is proposed for resource allocation. According to the author, future studies may include mobile IoT units in the proposed approach, where signal fading increases over the period.

The spectrum range which is used in 5G will be continued to expand into the entire spectrum era, probably starting from 1GHz up to 100GHz, to accomplish the basic properties of the 5G mobile network, along with the four application scenarios of Broader coverage, higher capacity, greater connectivity, and lower latency. The research work [17] provides an intrusive overview of CR technology and focuses on a recent important ongoing study in full-spectrum sharing toward four scenarios: auction-based spectrum allocation, full-duplex spectrum sensing, carrier aggregation-based spectrum access as well as spectrum-database-dependent spectrum sensing, The paper goes into detail about the best spectrum sensing technique, spectrum allocation approach, and spectrum access mechanism for each of the four 5G application scenarios to enhance spectrum usage efficiency.

The use of Internet access anywhere within the city using appropriate network design, as stated above, is a major stumbling block in the provision of smart city management across the city. Although 5G deployment has begun around the world, it is insufficient to fulfill all the requirements for future tech. As a result, CRNs are the best existing solution to address all of these issues for IoT, WSN, 5G, and beyond 5G network coexistence. Furthermore, to construct a 5G-enabled smart city, 5G must combine several enabling technologies to support IoT as well as a variety of other services [28].

The smart city is a new concept designed to enhance the standard of city life, and increase the efficiency of city control and services while also ensuring the city's long-term economic prosperity. Big data and the Internet of Things (IoT) have surfaced as essential accelerators for improved infrastructure. The usage of Internet connectivity within cities via appropriate network infrastructure is a basic challenge in the creation of smart city services. In its research endeavor, this study provides a smart governance framework to manage heterogeneous IoT systems [19]. The module's purpose is to provide a set of configuration functions that allow each VITAL-OS deployment to be customized for use in a smart city, as well as to propose a framework for an IoT-based smart city model to address the aforementioned challenges. G. Shyam et al. have investigated a garbage collection management strategy based on equipping waste bins with intelligence using a sensor-equipped IoT prototype. It can read, collect, and send vast amounts of Internet-based data. Such data, when put into a spatiotemporal context and processed by sophisticated and optimized algorithms, can be used to dynamically manage garbage collecting mechanism [14]. Using Sensor systems, S. Kumar et al. developed a system that monitors the amount of garbage in waste bins. This mechanism warns authorized parties through GSM/GPRS [13] as soon as it is discovered. A. Arber et al. studied a distributed cross-layer commit protocol (CLCP) for data aggregations and its support for IoT application query-based search [10].

A. Singh et al. proposed a technique employing infrared sensors to collect real-time data from waste bins and the Raspberry Pi2Development Board to transmit this data to waste management [6]. F. Fulianto et al. demonstrated a system that determines when a trash can is full. The system was developed to collect data and to send the data using wireless mesh network [4]. Al Mamun et al. have presented a new framework that permits the remote, real-time monitoring of solid waste bins via Zig-Bee-PRO and GPRS in order to facilitate the solid waste management process [3]. The system structure was built on a wireless sensor network, had three levels: smart bin, gateway and control station that stored and evaluated the data

for further use.
[20] S. Longhi et al. built a system based on sensor nodes and employing Data Transfer Nodes (DTN) to transmit garbage bin filling data measurements to a distant server via Data Transfer Nodes. W. Reshmi et al. created a system that utilizes a biosensor sensor, a weight sensor, and a height sensor to detect the overflow of waste in the trash can and the level of pollution caused by the release of poisonous gases from the trash can [25]. In this system sensors unit were used for sensing, microcontroller for controlling and for communication GSM module is utilized. V. Catania et al. [16] developed a method for waste collection in which bins' levels of fullness are monitored in real time by sensors installed within the containers. S. Islam et al. presented an integrated system that incorporated RFID, GPS, GPRS, GIS, and a web camera. The RFID reader fitted into collection vehicles would automatically retrieve a variety of customer data and bin data from RFID tags attached to each bin. GPS would provide the collection truck's location information [8].
J. Joshi et al. [26] have developed a solution for the Smart Bin, which is a network of garbage cans that integrates the Internet of Things with a Stack-Based Front-End strategy for integrating Wireless Sensor Network with a focus on software. N. Kumar et al. [17] have developed a smart alert system for garbage clearing by sending an alert signal to the municipal web server for immediate dustbin cleaning with proper verification based on the level of waste accumulation. They used an ultrasonic sensor, RFID, and Arduino UNO to monitor the level of rubbish in the trash can and notify the municipal web server if the bin is full.
He suggested that once the system verifies that the trash cans are completely full, they should be emptied using an IR device, GSM mode, and microcontroller. Once it's it, it should be reportable to the contractor's superior authority. It decides that the environment is clean and reduces the total number of visits made by the garbage truck. He designed the purposeful smart city and, consequently, a smart waste management system. It uses IoT to detect the amount of waste in trash cans, processes the data, and transmits it to a server for storage and processing. The procedure is administered by the Geographic data system.
The Internet of Things (IoT) is always evolving and offering novel answers to the common problems humans encounter. "Smart City" is an example of a term used to improve the quality of life for individuals. Strong waste management is a significant issue in many metropolitan communities, and a city's success is contingent on its ability to effectively manage the solid waste it generates. Using sensors, they collect information from trash cans and transmit it to a portal using LoRa technology. Using the MQTT (Message Queue Telemetry Transport) protocol, the information from numerous trash cans is gathered at the entryway and transmitted to the cover through the Internet. The standard position of the suggested systems is the use of the LoRa protocol for data communication, which enables long-distance data transmission with nearby low-power consumption when compared to Wi-Fi, Bluetooth, and Zigbee. Using a metal sensor, the wastes are being separated into metallic and non-metallic categories. And in other articles, magnets are used to separate metallic from nonmetallic materials, although the results are not precise. In some other papers, wet and dry wastes are detected using moisture sensors and then segregated accordingly. In addition, an odor sensor is utilized to separate degradable wastes that have an offensive odor. The most notable argument in waste architecture is that trash cans adjacent to open loopholes become avalanched well ahead

of schedule prior to the start of the subsequent cleanup effort. It may also be the cause of the spread of a number of diseases, as it causes a variety of dangers such as unpleasant scents and unsightliness in the affected area. Another article suggests a quick-response framework: authorization by sending an alert to the city server for immediate garbage can cleaning with appropriate authorization based on the location of trash filling. When it is time to empty the garbage, the controller of the RFID tag driver verifies that the task has been completed. Using the controller of this system, a local expert may monitor and arrange for complete control over how waste collection is actually performed. Wi-Fi module transmits the notifications to the Android application [27]. The majority of studies focus solely on waste management by detecting rubbish using ultrasonic or infrared rays and notifying the appropriate authority using GSM or WiFi. Few of the publications focus on the separation of waste materials. Also, not all waste materials are separated; only metallic and nonmetallic wastes, dry and wet wastes, and biodegradable wastes are separated. If the plastic also contains a little amount of moisture, it will be separated into the wet waste area, and if it has an artificial odor, it will be separated into the degradable waste part.

Chapter 3

Proposed Model

3.1 Smart Garbage Management System

The phrase ”smart city” refers to a novel concept that was developed with the goals of enhancing the standard of living in urban areas, boosting the effectiveness of urban processes and services, and ensuring the city’s continued economic growth over the long term. The Internet of Things (IoT) and large amounts of data have recently emerged as important enablers for the infrastructure of smart cities. The ”Internet of Things” (IoT) refers to a network of linked objects that may communicate with one another and exchange data. There are several instances of this, including automobiles, home appliances, and sensors located on the street. The data that is collected from these devices is stored in the cloud or on servers. This makes it possible to increase the efficiency of both the public and private sectors, which in turn results in economic benefits and improvements to people’ quality of life. Edge computing is used by a large number of IoT devices to ensure that the data that is sent across the communication network is limited to that which is most important and relevant. In addition, there is a security system in place to protect, monitor, and govern the transmission of data coming from the smart city network, as well as to prevent illegal access to the Internet of Things network that is hosted by the city’s data platform. We are proposing a smart city in which we will implement a smart education system, healthcare system, water supply system, security system, traffic management system, and anything else that is required for building a smart city. Additionally, we will attempt to integrate a CR-based modified 5G network in order to improve city communication. On the other hand, this article will provide a detailed explanation of the system for managing trash and will also cover its full implementation.

3.1.1 Model Design

E-Bin

The waste collection and disposal systems in Bangladesh and everywhere else must be improved. We have installed our e-recycling bin to fix this issue. Therefore, let’s define ”E-bin.” The term ”E-bin” refers to fully automated waste bins that employ a number of sensors to decide by themselves whether they are full or not. This decision will influence whether the garbage can be collected or not. The bin can communicates in real time to a server, enabling smooth operation. A NodeMCU, an

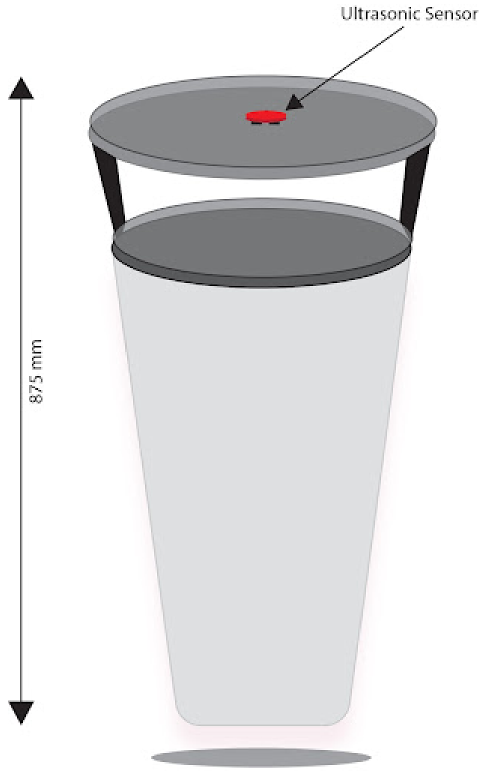


Figure 3.1: E-Bin

ultrasonic sensor, and a GAS sensor were used to automate the garbage can. In this configuration, NodeMCU serves as the microcontroller. The microprocessor in the bin monitors the bin's status every 10 minutes. The microprocessor refreshes the dustbininfo database with the most current information when the bin status passes the threshold. For system management, the dustbininfo database holds date and time information. Next, a table labelled worker holds information about workers, including date, time, location, name, phone number, etc.
Using an ultrasonic sensor, the distance is calculated inside the waste container. This sensor can detect height using reflected sound and a certain amount of time. We made a determination based on a threshold value for the bin. Our system's automation also includes a gas sensor. This sensor is capable of detecting any flammable or hazardous gas. Using a piezoelectric substance, gas concentrations are measured. If a gas leak is detected, our system can respond promptly due to this sensor. When both sensors are used, our system is able to transmit data to the cloud.

System

The flowchart of our system may be seen above. There, we are able to see the connection and communication that exist among all of the processes, the database, and the bin. The microcontroller comes up at number one on our list. The microcontroller has the ability to create a connection to the internet. We have developed an API so that data may be sent to the server. Users with shared authorization or administrative privileges are the only ones who can access the API. In order to get data from the server, we have used MySQL. FreeMySQLHosting was the database hosting service that we chose, and we signed up for a user account on that service.

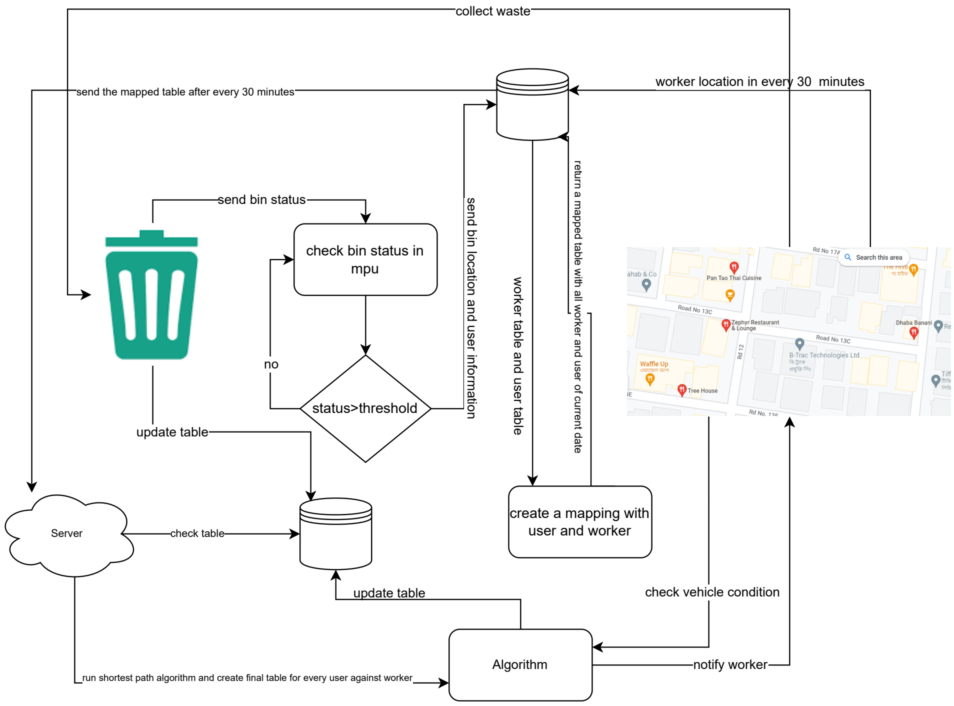


Figure 3.2: Proposed Smart Waste Management System

This user acts as our administrative control panel.
This user was utilised by us in order to interface with the server and carry out our SQL operations, which included inserting, deleting, selecting, and updating data. We were able to see real-time locations on Google Maps by using the API key for Google Maps. When we have attempted to get access to the current position in the vehicle using our microcontroller, we have made use of this geolocation API key. Both a gps module and a geolocation javascript function are available in our vehicle for use in the data collection process in real time. This API key is required in order for this javascript code to have access to the map.
There are three different kinds of users for our system.

User:

User: The user will get our service after they have successfully completed the registration procedure. The user may also make a complaint or provide comments. Users are able to submit requests for any kind of assistance.

Worker/Vehicle:

They are the final user of our service. They engage in labour in the field. They also put in a request to be workers via the registration process, and we used to evaluate their physical condition before sending them out to work. Not only that, but we also assessed the workers' physical conditions as part of the worker selection criteria. The workers have to travel from house to house in order to collect everyone's trash.

Admin:

Admin: Both a web version and an app version of our system have been developed so that we can monitor it more effectively. The administrator has access to every element of the system. He is able to initiate a call, send a message or email, as well as see the position of the worker and the user from inside the system.
This is a condensed overview of our system that touches on all of the most important aspects of our system.

Service Area

The service region has been established based on the sign-up information. In the registration form, we collect the address or user and the worker. Additionally, we get the position using the geolocation API. When there are more users in a certain region, we allocate more workers from neighbouring areas.
Workers transport trash to the specified city corporate container or landfills. Two municipal corporations are responsible for garbage decomposition across the whole city.

3.1.2 Proposed algorithm:

Heuristic Value Generator

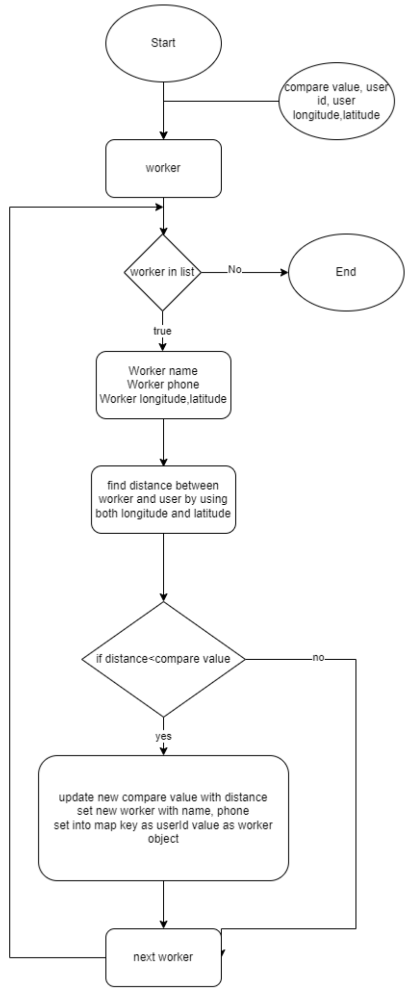


Figure 3.3: Flowchart Of Proposed Algorithm.

In this algorithm we get the minimum distance and find out the heuristic value for the A* search by the equation 2.1 which also gives us the information about the user against worker.
We use two 2d arrays, one for the user and another for the worker. The array contains all additional information like user ID, longitude and latitude, date, time. For the worker array we have worker name, date, time, email, phone number, longitude and

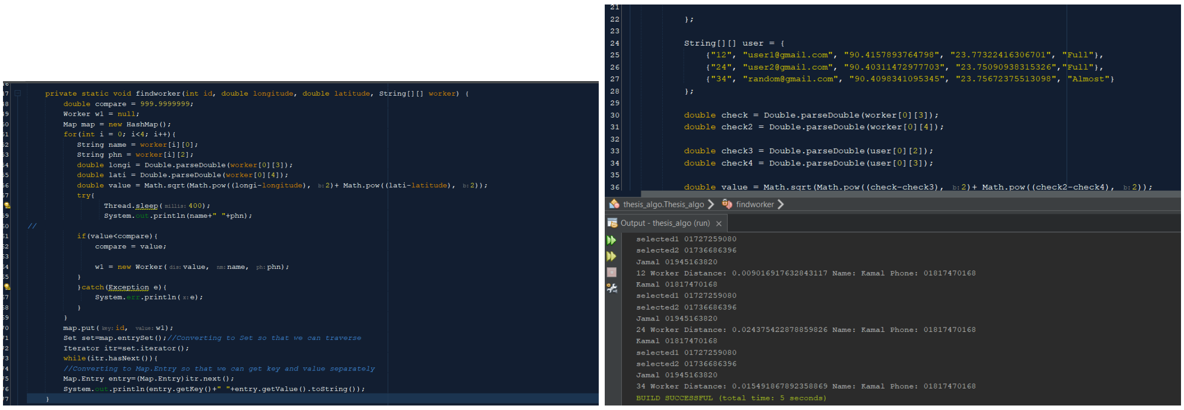


Figure 3.4: Running Code Of Our Algorithm.

latitude. We loop through for user and find out the worker with minimum distance and mapped them user against worker with phone number distance and name. In order to find the minimum distance between user bin and every worker we used the formule of measuring distance among 2 points: (also available at 2.1 :)

$$d = \sqrt{(longitude_{user} - longitude_{worker})^2 + (latitude_{user} - latitude_{worker})^2} \tag{3.1}$$

Depth Defined A* Search

A* search is a scanning algorithm that assist to identify the best route which is also the quickest route. For the A* search algorithm to function, we need heuristic values, which are generated by our algorithm heuristic value generator. But the issue with A* search is that it returns a solution from a single beginning node to a single destination node. Therefore, workers must collect waste from one container at a time. And must return to the original starting location, which is inefficient and costly. We changed the method and developed a depth-defined A* search technique to solve this issue.
In this algorithm, worker and waste collection tables are iterated in the shape of a tree. In addition, our algorithm will provide a collection of tables including several bin requests for a single worker. So, a single worker will be allocated to numerous bins at once, and this procedure will continue. In this process, there is also the possibility that numerous workers will be picked for the same bin. We've used the heuristic value to tackle this problem. The designated worker will be the one with the lowest heuristic value for the given bin. By conforming to this procedure, the issue of worker repetition is resolved.
In this algorithm, we are primarily concerned with the tree's depth. The A* search will begin at the root node and go from level to level. Follwing steps of this algoritham:

- Worker's position is the starting point.
- Bin's location is the leafs of the tree.

- Leaf's are decorated by the requested time.
- A* search will move from level by level.
- Selected bin in every level will be mapped.
- In the depth of the tree we will get a final mapped for the particular worker.

The flowchart of our modified A* search is given below 3.5: The working process of

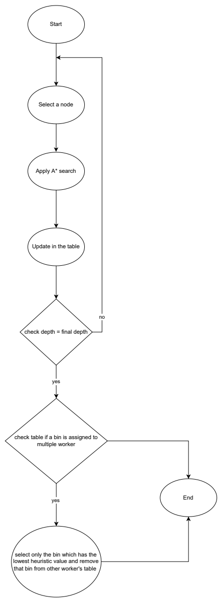


Figure 3.5: Flowchart of modified A* search

our modified algorithm is given below 3.6: From the graph 3.6 we can see that the

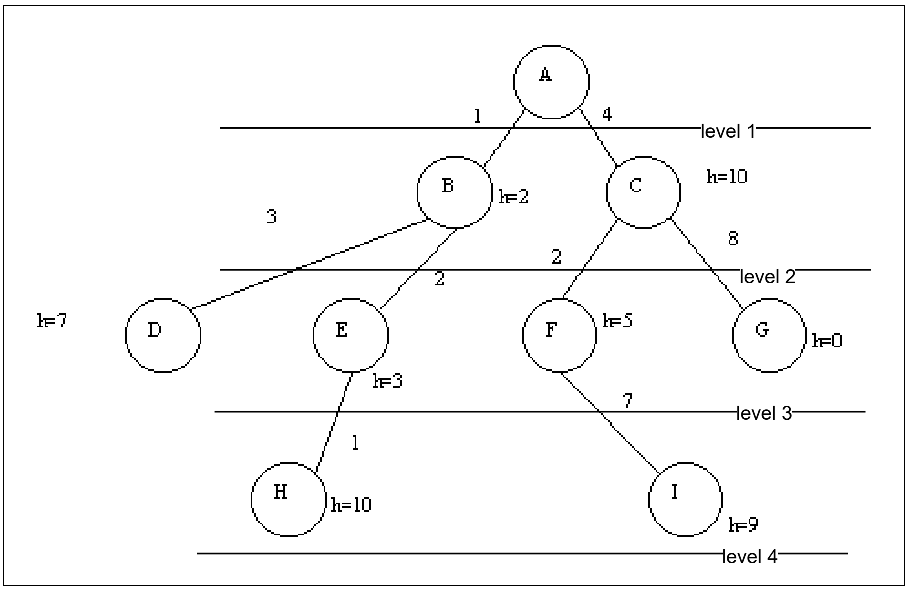


Figure 3.6: Working process of modified A* search

depth of the tree is level 4. Our algorithm will go to leaf node by level by level. In the level 2 we have 2 branch we will apply A* for the both node in level 2 and this

Table 3.1: Mapped Table After Running Algorithm

Worker ID	Path	Cost	Selection	End
1	A- >B	3		
1	A ->->B ->D	11		True
1	A ->B ->E	6		
1	A ->B ->E ->H	14	**Selected**	True
1	A ->C	14		
1	A ->C ->G	12		True
1	A ->C ->F	11		
1	A ->C ->F ->I	22		True

will create a value. Here, we can see our worker will have totally 2 different path with some assigned node.

If we iterate our algorithm until it reached to the depth of the tree we will have some mapped table like 3.1. From the table 3.1 we can see that there are 4 end path but the selected path is only one. Why? From the tree, we can see that on level 2 there is a leaf node D that creates the terminal node, but our algorithm will go to the depth in order to choose as many bins as possible simultaneously. By operating in this approach, we have identified two potential routes. In the end, though, we have two paths with the same number of iterated nodes, but only one of them corresponds to the user's chosen route. Our algorithm selects the route with the lowest potential cost. One of the last two paths costs 14, while the other costs 22. The algorithm has chosen the lowest option.

Now, the issue may arise as to what will happen to the leaf nodes on levels other than the depth. After each completed iteration, the nodes that were picked in a route will be removed. And create a new tree with new requested bins.. We have previously confirmed that we have constructed our tree such that new nodes are merged at the moment when our server receives a request for waste collection. Therefore, the leaf nodes from the prior tree will be placed at the root of the new tree, and the newly requested bin nodes will be merged with the previous tree in ascending order. This is how the leaf node issue has been resolved.

3.1.3 Working Process

In Bangladesh, there are a variety of landfills where garbage continues to gather, with the smell and size of the landfills rising regularly. Obviously, nobody wants to go through that and remove the waste collection. What if a machine could fix it instead? Imagine a machine that not only sorts recyclables and nonrecyclables, but also rummages through the trash bin. Effectively, all recyclables may be recycled, while non-recyclables may be incinerated, buried, or disposed of in any way deemed acceptable. In addition, there may be other disposal alternatives for the non-recyclable waste in the pile. Here, we will provide a Smart Garbage Management System consisting of a Smart Bin and a simplified process. In our design, IoT-based

edge nodes transmit unprocessed data to the cloud, and the "FreeMySqlHosting" cloud platform is used to store and display the data acquired by the nodes.
The proposed smart city network model aims to deal with the issues of data scalability and flexibility while deploying cognitive technology-based smart city solutions. Modern intelligent cities create a vast amount of data, which helps to turn existing cognitive programming-based technologies into much more precise and reliable outcomes. As a result, smart city infrastructure must enable several cognitive computing-based systems to benefit from a variety of common flows of human and environmental contextual data. Our predicted plan is to create a smart infrastructure model, as depicted in Figure 4 which depicts the stages involved in creating this smart city network model.[1]
Smart city infrastructure, inside the era of the Internet of Things (IoT), should increase citizens' quality of life while simultaneously boosting security. CIoT architecture will be used to analyze observational data based on previous knowledge, implement strategic judgments, and carry out responsive and controlled activities in order to develop a smart city.[29] In the cognitive computing layer, machine learning, processes of data preprocessing, data analysis, and cognitive trait extraction are covered. It generates an algorithm according to feature selection, allowing to give more customized smart city solutions. The network layer will act as a link between the IoT and the data. The data layer describes the sort of human activity data collected via sensors. Figure 5 shows an early version of the proposed smart city network model.
After that, we'll be able to develop our proposed smart city network model by combining all the layers into a single platform.

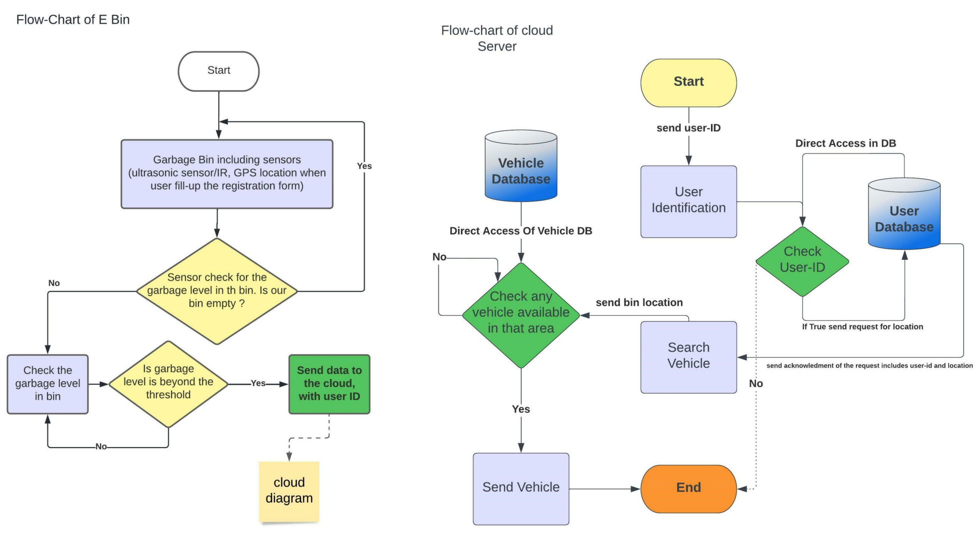


Figure 3.7: Workflow for Smart Management System

The graphic [3.7] illustrates how information is sent to the server. In the beginning, our microcontroller checks to verify whether the container is empty. If our bin is empty, the procedure will be repeated until garbage is present. If there is garbage in the bin, our microcontroller determines the limit of the garbage, or how full the bin is. If the waste limit is greater than the threshold, the processor will remain in

the loop until the threshold is achieved. If the garbage exceeds the threshold, the microcontroller sends the status, present condition, threshold, location, date, and time of the bin to the server.
The graph on the right depicts the backend work process. Our microcontroller transmits to the server the bin's date, time, and position. The server will then validate the user's credentials. We get all user-related information from the user database. This service is only available to registered users. When someone completes the registration process, we get all of their information, including their location, name, email address, phone number, and so on. After the verification procedure, we transmit the request's location, date, and time to a separate process called search cars. This process has direct database access. Real-time updates are performed on the worker database. Our automobile is equipped with a microcontroller and GPS module. The microcontroller has a worker identification number and sends the worker's position every 30 minutes. We update the worker table using the microcontroller-sent worker ID. The act of searching for a car determines whether or not there is a vehicle available at that place. This method uses algorithms for choosing the shortest route to find the vehicle closest to the container based on where the container is. However, if the system recognizes a vehicle, it will communicate with worker and send the position of the trash can to the vehicle. And this is the whole operation of our system.
Circuit diagram is given below:

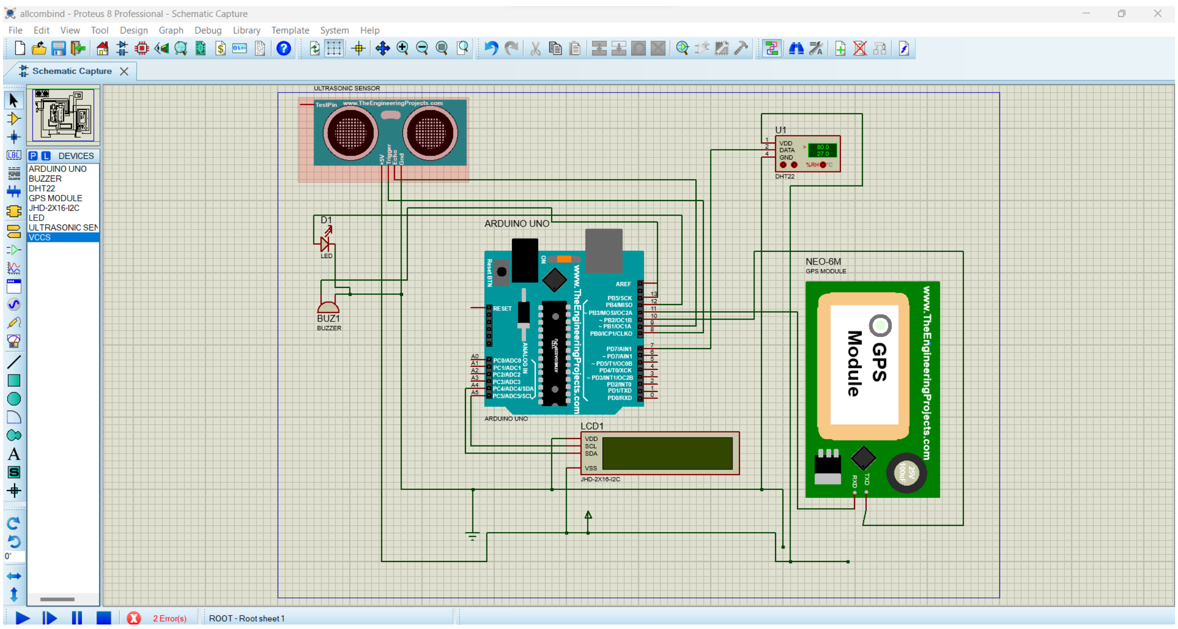


Figure 3.8: Proteus Diagram for E-Bin Module

As stated before, NodeMCU serves as a microcontroller, and it is the microcontroller's responsibility to communicate data from the bin to the server. NodeMCU contains a wifi module that is connected to the user's local wifi network. Because we want to construct a smart system and because it is increasingly conceivable that a state, such as India, would be totally covered by a wifi system, we are implementing a wifi system. All of the ultrasonic sensor, humidity sensor, LCD with buzzer, and LED are connected to our microcontroller. We determined our cutoff threshold to be 10 centimetres from the top. This indicates that the distance is being measured

from the top. If the distance is less than 10 cm, our microcontroller will notify the server that the container is filled. If the spacing is between 10 and 20 cm, then the bin is virtually full. As previously stated, we are connecting the user registration data with the bin address. With every acknowledgement, we will send the date, time, location, current status, threshold, and situation.
From the figure [3.9] we can see User registration gets all user information and stores it in our database and all data is encrypted. The user registration website we had used a geolocation API by Javascript and asked permission to track the current location, and after tracking the location, a user could register for our system. Without a location, our registration will not be complete. We get this location of the user to send our dustbin at his/her house, office or industry.

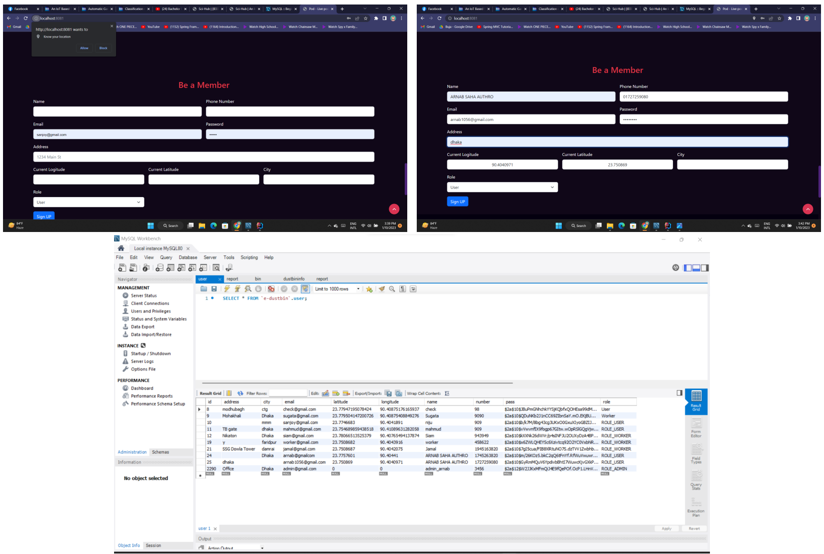


Figure 3.9: User Registration UI

After all of the conditions have been met, our microprocessor will then access a url in the local browser while the wifi is connected. The URL is nothing more than a request to obtain all of the information in one place. For the purposes of google security and double security, the information was first received in a google spreadsheet, and then the data were sent to the server directly from the spreadsheet. In order to get the information from the url, we made use of app script. After creating a custom url, we linked the app script to it and then sent an API through. After obtaining the API, we retrieved the data and obtained it when our microcontroller made contact with the url. We were able to get data in real time from the microcontroller and transfer it to the spreadsheet using this method. Before transferring data into spreadsheets and servers, we can see the current date and time below: Next, we used

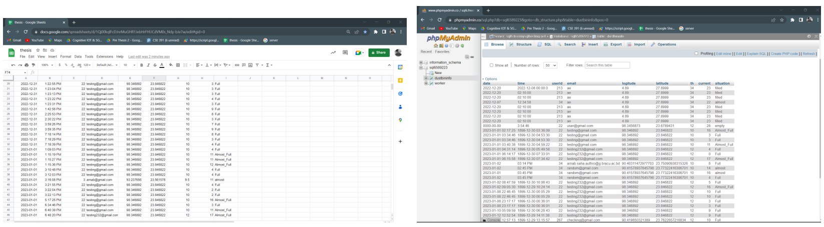


Figure 3.10: Raw Data before sending to the server

a second app script connection to transfer spreadsheet data to our server we can see that from the graph [3.12]. After executing the first url for transmitting data from the microcontroller to the spreadsheet, a second app script url was executed to send the final row of the spreadsheet to the client. It may be questioned why the final row is picked to transmit data to the server. Note that our code was written in a synchronized fashion, such that it would first push real-time data to the spreadsheet and then access the URL responsible for delivering data to the server. In between two URLs, we specified a five-second time period. Because each HTTP response and HTTP request need a certain amount of time in milliseconds to establish a secure communication. And it is proven that the maximum possible duration is 2.3 seconds. For safety purposes, a five-second delay was implemented. However, our primary loop for determining if the trash can is empty is often 30 minutes behind schedule. From the below pictures, we can see how our real time data is transferred.

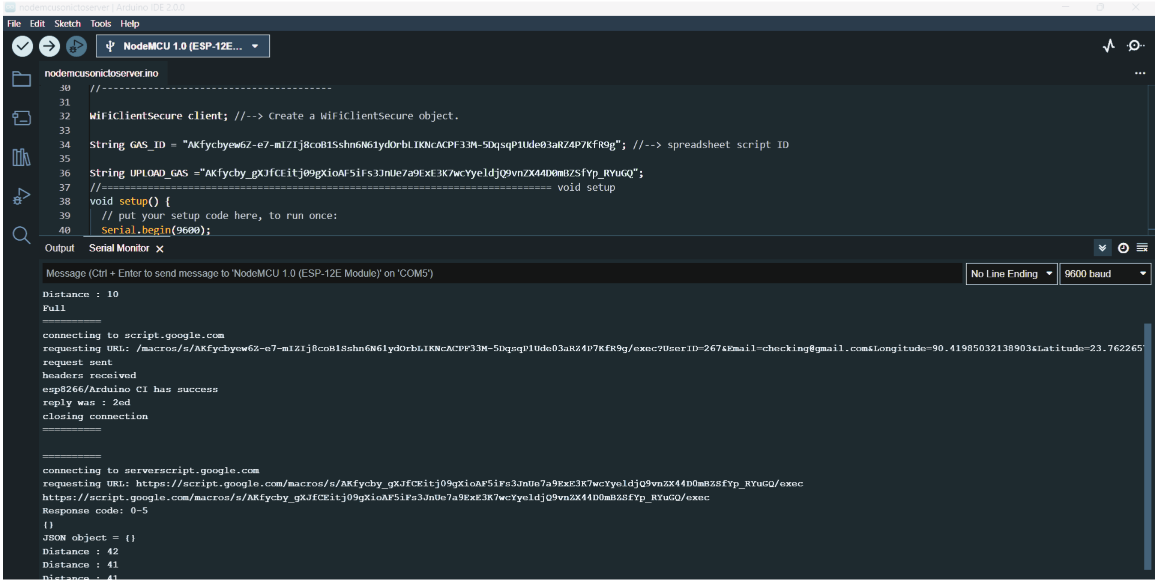


Figure 3.11: Arduino Compilation

After dustbin being full and fulfilling all conditions we can see two is hit by our microcontroller synchronized way. The first URL is to store data in the spreadsheet, and the second URL is to store data from the spreadsheet to the server. We can see the **HTTP request** and **HTTP response** from the picture, and our URL is working perfectly. Now after hitting the URL the apps script code will be executed and receive the data and decrypt the data. This code will fetch the API and retrieve

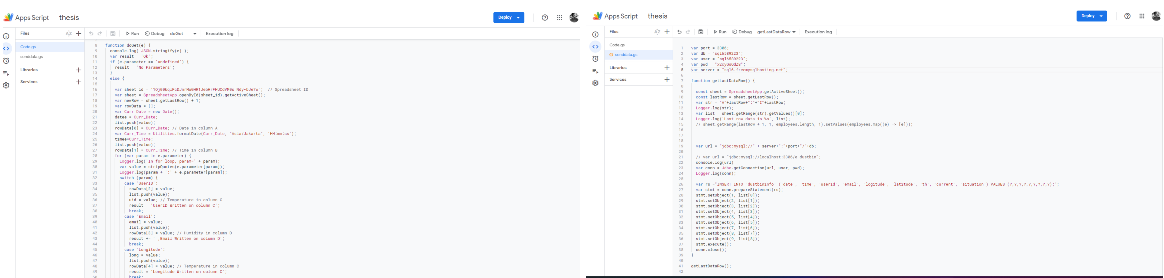
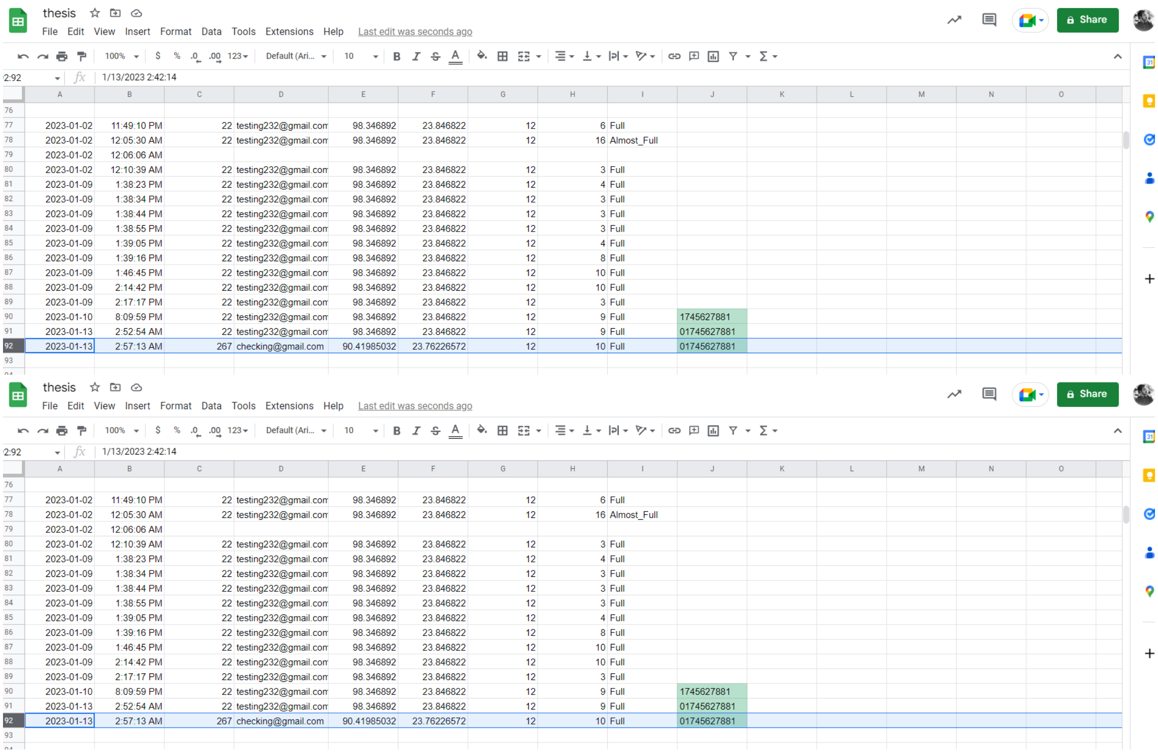


Figure 3.12: Appsheet Code UI

them. First, the code will retrieve data and store it column by column in the spreadsheet. Second code is to create the connection with the database and after connecting the database we used JDBC to use SQL code. This sql code will store data in the database. After the execution of the code, our data will be in the spreadsheet as well as in the server. You can see that from the picture above. Following the above steps, our data is received from the end users to the server.



	A	B	C	D	E	F	G	H	I	J
76										
77	2023-01-02	11:49:10 PM	22	testing232@gmail.com	98.346892	23.846822	12	6	Full	
78	2023-01-02	12:05:30 AM	22	testing232@gmail.com	98.346892	23.846822	12	16	Almost_Full	
79	2023-01-02	12:06:06 AM								
80	2023-01-02	12:10:39 AM	22	testing232@gmail.com	98.346892	23.846822	12	3	Full	
81	2023-01-09	1:38:23 PM	22	testing232@gmail.com	98.346892	23.846822	12	4	Full	
82	2023-01-09	1:38:34 PM	22	testing232@gmail.com	98.346892	23.846822	12	3	Full	
83	2023-01-09	1:38:44 PM	22	testing232@gmail.com	98.346892	23.846822	12	3	Full	
84	2023-01-09	1:38:55 PM	22	testing232@gmail.com	98.346892	23.846822	12	3	Full	
85	2023-01-09	1:39:05 PM	22	testing232@gmail.com	98.346892	23.846822	12	4	Full	
86	2023-01-09	1:39:16 PM	22	testing232@gmail.com	98.346892	23.846822	12	8	Full	
87	2023-01-09	1:46:45 PM	22	testing232@gmail.com	98.346892	23.846822	12	10	Full	
88	2023-01-09	2:14:42 PM	22	testing232@gmail.com	98.346892	23.846822	12	10	Full	
89	2023-01-09	2:17:17 PM	22	testing232@gmail.com	98.346892	23.846822	12	3	Full	
90	2023-01-10	8:09:59 PM	22	testing232@gmail.com	98.346892	23.846822	12	9	Full	1745627881
91	2023-01-13	2:52:54 AM	22	testing232@gmail.com	98.346892	23.846822	12	9	Full	01745627881
92	2023-01-13	2:57:13 AM	267	checking@gmail.com	90.41985032	23.76226572	12	10	Full	01745627881
93										

Figure 3.13: Raw Data after sending to the Server

Next, we installed a microcontroller (NodeMCU) and a GPS module (NEO-6M) in each car to track employees' whereabouts. Each of our microcontrollers is linked to the city's local wifi network and stores essential worker data such as id, name, email, phone number, vehicle status, and position. Each employee has their own unique set of contact details—name, email address, and phone number—stored in a manually created, constant variable called worker id. Because each worker is assigned to a particular worker.

We used three criteria—vehicle weight, vehicle odor, and worker health—to determine the vehicle's state. How do these three indicators determine the sustainability of a vehicle? Our first step is to collect data about the car, and then we'll see whether any of it indicates the presence of any potentially harmful gasses. If our sensors detect a terrible smell, they will mark the van as full and notify the driver to take the garbage to the dump. In the absence of any detectable odors or toxic gasses, our program will determine whether or not the trash can is full based on its weight; if the trash weighs more than 70 kilogrammes, it will be marked as full. If the ultrasonic sensor detects height is less than 30 centimetres (1 foot), however, the car will be considered to be full even if their weight is below 70 kilogrammes. The aforesaid factors are analyzed, and if a worker's health is less than 70%, their weight (up to 50 kg) is considered, and the vehicle's status is set to full.

We determined the vehicle's mass by measuring the force exerted on its surface using a force sensitive resistor. We all know that: $\mathbf{F} = \mathbf{ma} = \mathbf{mg}$ And without any other acceleration, our a = g which means W = mg. For detecting gas, we have used the SenSmart 3100 EC Gas Detector and MQ-5 gas sensor. This sensor detected

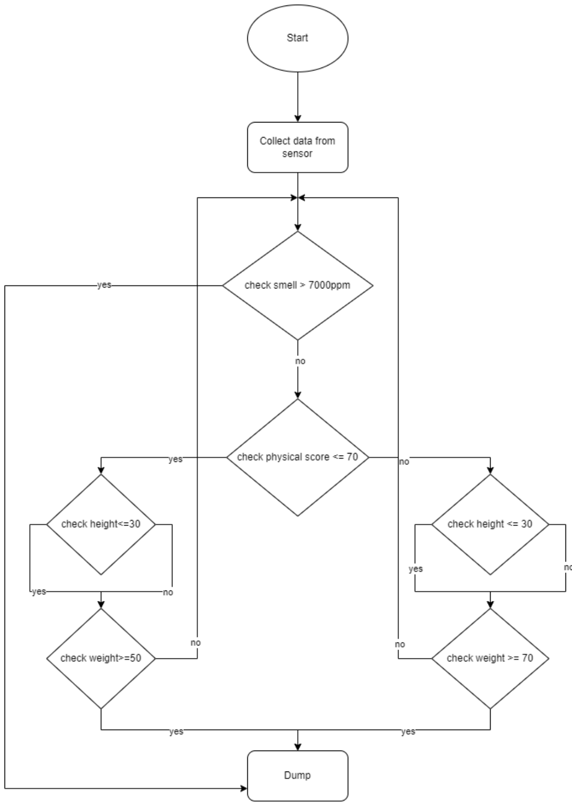


Figure 3.14: Workflow of vehicle

the gasses from the van. In order to check the worker physical condition we have approached the monitoring system against worker ID. When a worker collects his van, we measure his temperature, pressure, and other criteria and store them in the database, and for purposes of assigning the worker, we check his condition. In order to get the location of the vehicle, we have followed 2 methods: we have a GPS module connected to the van, and GPS is connected to the NodeMCU. The RX, TX pin is connected to the digital pin 10,11.

Another method is that we have used a Google Maps API key with geolocation authentication. By this method we get the real time data of google map location with latency 30 meter.

The reason behind using this method is that we know that GPS modules don't work indoors and it takes too much time to get the satellite connection, but the geolocation approach gets the location from local WiFi. It first connect to the available WiFi in NodeMCU than from microcontroller it send acknowledgement to the router for location if it is not available than from router move towards the other router connected with this router and this goes on until it get the location which is much more faster than the getting connection with satellite.

This method allows us to pinpoint the van's precise position and report it to the server in real time. As soon as we get the user's data from the server, we execute our algorithm to assign them to a certain worker. Our hybrid selection algorithm has been applied to generate a user ID vs. worker information map, however depending on the distance and selection condition, there may be more than one worker. By this algorithm we get the heuristic value also. Than we use this heuristic value and the mapped information in the A* search algorithm to select the perfect worker.

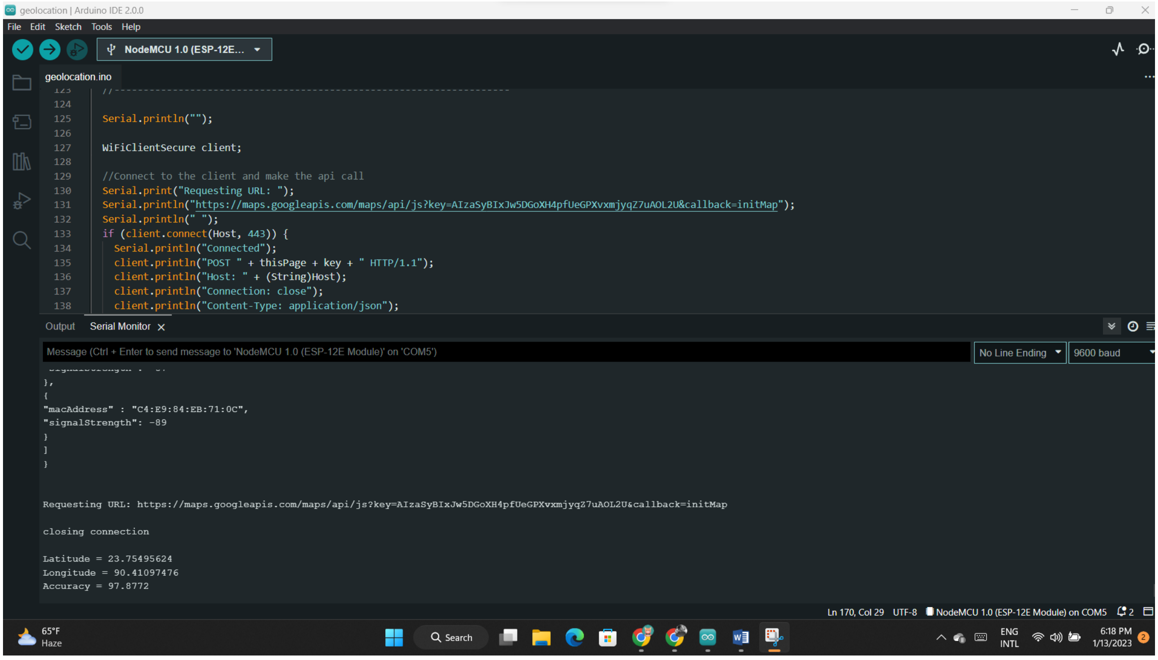


Figure 3.15: Fetching GPS location from google map API

We use SQL to retrieve data from the worker and bin tables, which we then use in our hybrid algorithm than in the a* search algorithm. The table we get from database is given below: We used this table to use in our algorithm and our algorithm will create a new mapped table which refers to the hurestic table for the A* search.

Options

date	time 1	userid	email	logitude	latitude	situation	time	name	vehical_longitude	vehical_latitude	status
2023-01-02	02:45 PM	34	random@gmail.com	90.41578937645798	23.77322416306701	almost	02:56 PM	Jamal	90.4098387622404	23.752539879769998	Empty
2023-01-02	02:45 PM	34	random@gmail.com	90.41578937645798	23.77322416306701	almost	03:14 PM	selected 1	90.4154515415042	23.754778885967806	Empty
2023-01-02	02:45 PM	34	random@gmail.com	90.41578937645798	23.77322416306701	almost	03:06 PM	Jamal	90.4098387622404	23.752539879769998	Empty
2023-01-02	02:45 PM	34	random@gmail.com	90.41578937645798	23.77322416306701	almost	03:14 PM	selected 2	90.42227735613994	23.76626408356814	Empty
2023-01-02	03:14 PM	34	arnab.saha.authro@g.bracu.ac.bd	90.40311472977703	23.75090938315326	Full	03:06 PM	Jamal	90.4098387622404	23.752539879769998	Empty
2023-01-02	03:14 PM	34	arnab.saha.authro@g.bracu.ac.bd	90.40311472977703	23.75090938315326	Full	03:14 PM	selected 2	90.42227735613994	23.76626408356814	Empty
2023-01-02	03:14 PM	34	arnab.saha.authro@g.bracu.ac.bd	90.40311472977703	23.75090938315326	Full	02:56 PM	Jamal	90.4098387622404	23.752539879769998	Empty
2023-01-02	03:14 PM	34	arnab.saha.authro@g.bracu.ac.bd	90.40311472977703	23.75090938315326	Full	03:14 PM	selected 1	90.4154515415042	23.754778885967806	Empty
2023-01-02	03:45 PM	34	random@gmail.com	90.41578937645798	23.77322416306701	Full	02:56 PM	Jamal	90.4098387622404	23.752539879769998	Empty
2023-01-02	03:45 PM	34	random@gmail.com	90.41578937645798	23.77322416306701	Full	03:14 PM	selected 1	90.4154515415042	23.754778885967806	Empty
2023-01-02	03:45 PM	34	random@gmail.com	90.41578937645798	23.77322416306701	Full	03:06 PM	Jamal	90.4098387622404	23.752539879769998	Empty
2023-01-02	03:45 PM	34	random@gmail.com	90.41578937645798	23.77322416306701	Full	03:14 PM	selected 2	90.42227735613994	23.76626408356814	Empty

Figure 3.16: SQL Table For Running the Algorithm

We built an app with extensive monitoring capabilities, allowing the admin to do things like see requests, make changes to requests, remove requests, get in touch with users, and even track their movements using a map. Additionally, the administrator may see data classified by month, user, circumstance, threshold, and so on. This is the landing page for the application.
All requests for garbage pickup are shown here along with the times and dates they were received.The bin's location may be seen by our admin, and they can also write an email, make a phone call, or send a text message to the user. To send an email, the admin simply enters the recipient's email address, and our app will open the appropriate email client. To make a phone call, the laptop version of the app will prompt the user to choose an app to handle voice calls and text messages, but the

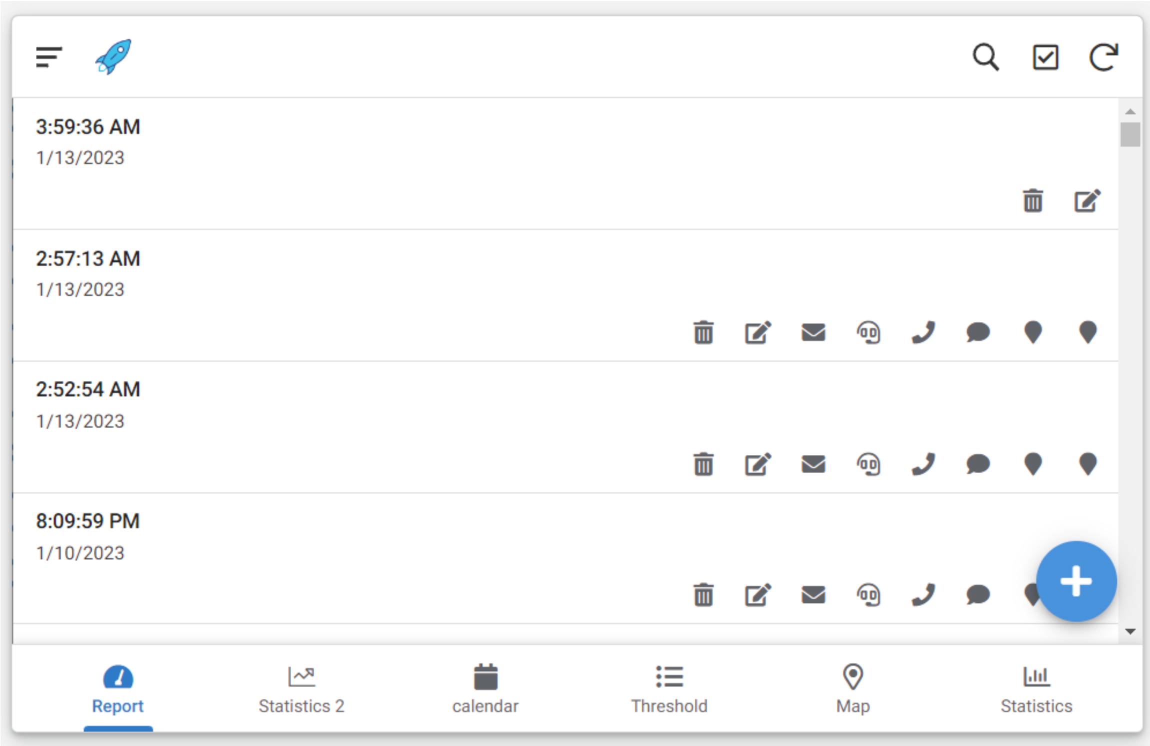


Figure 3.17: Homepage of System

mobile version will immediately begin dialing the number displayed in the url bar. And for location our software will redirect the admin to the google map with the longitude and latitude of the user and the admin can see the live view of the map.

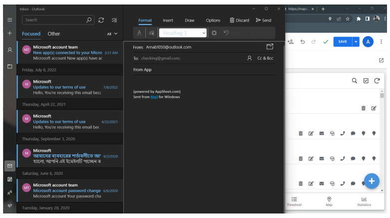


Figure 3.18: Sending Email From the App

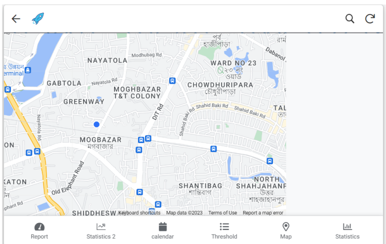


Figure 3.19: Real Time Google Map From The App

Secondly, we have added a calendar section. From the calendar section, administrators may see the number of requests for garbage pickup segmented by day, week, or month. This will help to approximate daily waste production, collection request, disposal of waste, etc. Furthermore, we have another page for showing statistics with time against request. From this graph, the admin can understand at which time how many requests are coming.

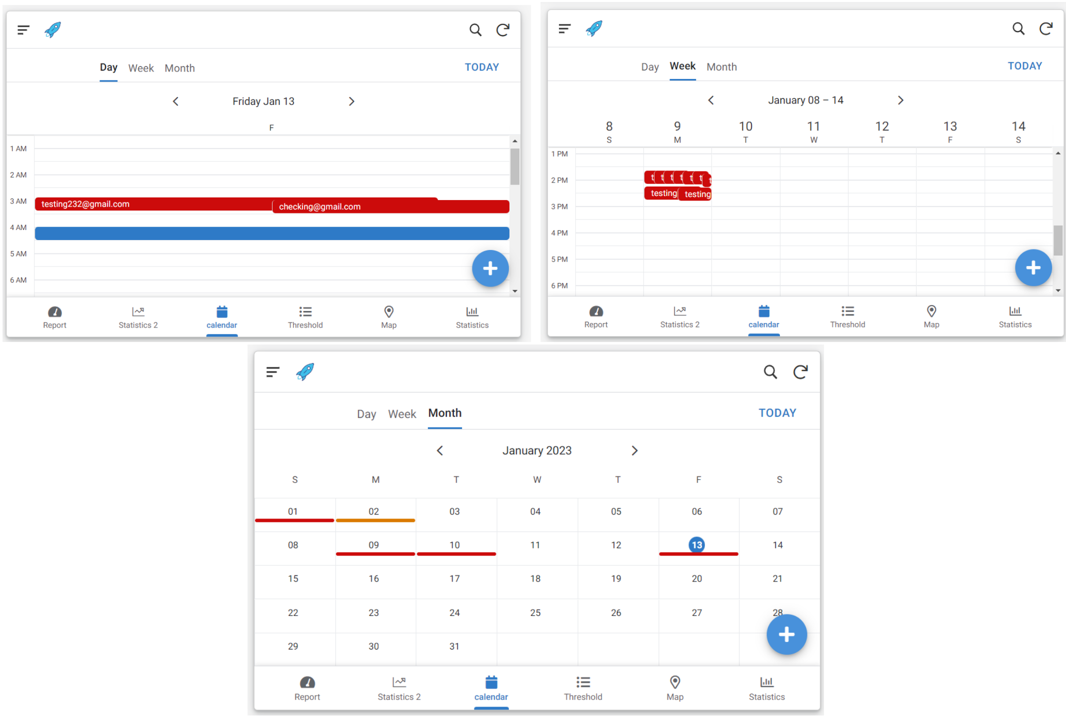


Figure 3.20: Calendar showing waste collection request from the bin based on Day, Week, Month

Not only that admin can also visit 2 more statistics containing the threshold limit against time against userID. From this graph, we can track which user is using the most and requesting multiple times at which time. From this result, the admin can make a detailed analysis from which area is producing a high amount of waste. So, admin can allocate vehicle acccording to the demand of the specific area. On that basis, admin can manage the system for daily vehicle allocation and disposal of waste.

First Fig 3.21 shows the bar graph of current bin status against time. From this graph admin can visualize that in which time thw maximun amount of garbage is produced and in which time most of the request is coming for garbage collection.

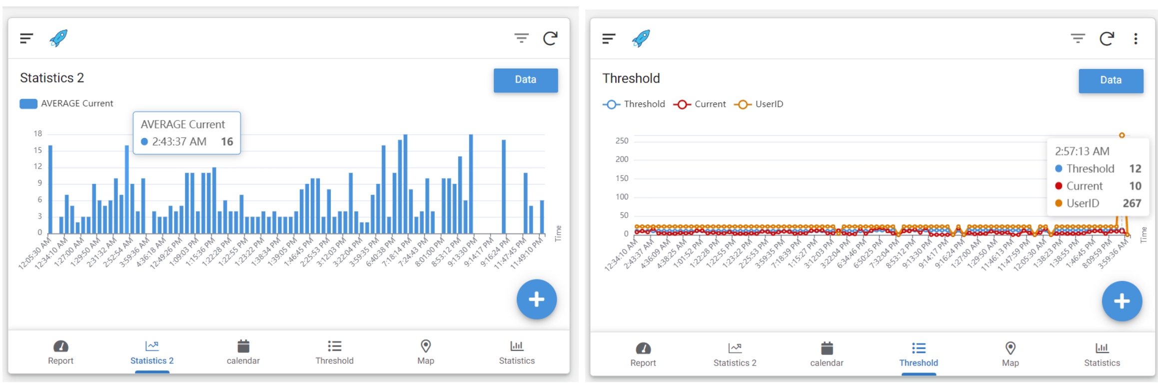


Figure 3.21: Threshold & UserID against time & current status

We have also generated a pie chart with all other additional information. From all of the data and the statistics, admin can access all the real-time information regarding our system and control them. Like admin can see how many dustbin are full, almost full, half filled or empty. Also for a specific status admin can see more details by pressing the status. So if the system face any unavoidable error so the admin manually assigns a vehicle to collect the waste. Also, for emergency admin can modify or cancel any request.

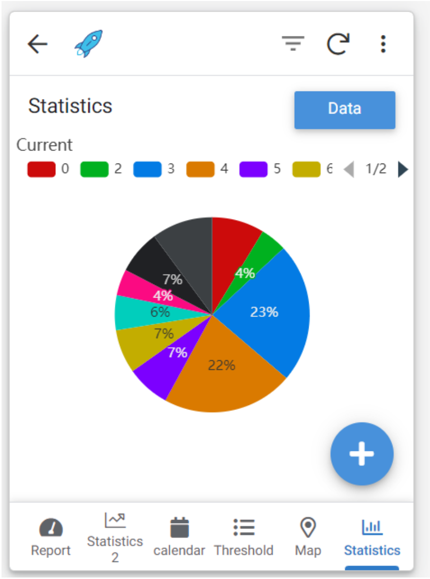


Figure 3.22: Pie Chart

3.2 Model Extention

A smart hub may be a Zigbee/Z-Wave-based smart bridge, a smart speaker, or a smartphone application. Smart home products such as smart lights, smart coffee makers, smart thermostats, video doorbells, smart security cameras, and smart door locks will connect either directly to the home WiFi or to a central hub.
PoE can power sensors, lighting, HVAC systems, elevators, and fire alarms in a smart building, in addition to USB-C laptops, TV and computer monitors, shades, refrigerators, and room air conditioners. A smart building can, for instance, utilize the data it collects to change the blinds to let in more natural light, thus reducing the use of electric lighting. Connecting lighting, shades, and HVAC systems, for example, allows building operators to automatically alter temperature, shades, and lighting according to time of day and occupancy.
Furthermore, having class rooms with VR headset will help the students visualize the topic as the headset application places the user in a virtual environment, cuts off all forms of distractions and 'immerses' the learner in the environment. The conductors that are connected to the capacitor sensor(s) will be positioned in such a way that they will fit into the vacated spaces. If there are more questions than there are buttons, we won't remove any questions; rather, we will utilize one of the buttons as a "next page" button so that you may go to the next page of questions. When the capacitor sensor is linked to the microcontroller, the microcontroller will be able to get this information. The microcontroller incorporates a Wi-Fi module, which enables it to interface with a database and send the unique identity of the capacitor as well as the time at which it was touched to software that is stored

in the cloud. The computer is able to produce statistics on the amount of time that students spent on each question by using the data that was submitted by the students. After learning that the vast majority of schools give student ID cards that feature an embedded RFID tag, our group came to the conclusion that including an RFID reader was the best course of action. With the use of this tool, the examiner will be able to authenticate student IDs, track student presence during the whole of the test, and conduct queries depending on a student's data.
We developed a fabric that is effective for monitoring in MR situations by using FBGs as sensing components in order to avoid adding artifacts into MR pictures. The ballistocardiography signal was used in order to monitor the subjects' respiratory rate in addition to their heart rate at the same time. One of these measurements is the respiratory rate, which is defined as the ratio of the amount of time spent inhaling to the amount of time spent exhaling (RR). The ratio of the amount of time spent breathing into the amount of time spent breathing out, as well as the respiratory rate (RR), and heart rate are all components of the predictive estimate used to treat emerging health issues such as hyperventilation and tachycardia (HR). Calculating a subject's heart rate requires the data from a single sensor to be run through the proper filter stages, as well as being subjected to an FFT analysis. The data from one subject suggested that the heart rate (HR) would remain the same during apnea and quiet breathing (0.96 Hz during apnea and 0.93 Hz during quiet breathing), whereas the data from the other subject suggested that the HR would increase during apnea (1.7 Hz) in comparison to the HR when the subject was breathing normally (0.9 Hz).
Water pipelines having point detection sensors having probes touching the water simultaneously will detect the water leakage and trigger an alarm in confined areas, when the leakage is detected. We usually see advertisements regarding various different water purifiers, each claiming to give 100 percent pure drinking water. The device we have been building for this project does not make water absolutely clean for drinking, however, it can take in the dirtiest of dirty water which is later purified to the extent where this water can be used in a multiple venture of applications, like fire hydrant, agricultural use, etc. Also, if the pH level seems to be unchangeable, that is no matter how much filtration is carried out, the water is not being cleaned at all, then that amount of water will be dispersed into the ground. Once enough of the water is collected, that is, the reservoir limit has been reached, no more water is taken in. These rise in need may occur due to lack or pollution of regular water which may lead to dire situations unless the water from the agencies is provided.
The CCTV footage covering the areas will detect the free parking spots with the help of digital image processing and with the help of algorithm will be used to detect the location and the output information will then be store in the system, anyone using that application and searching the available parking slots will be able to see the free parking spots near them .The System will help the users with unique identification using the vehicle registration number to register and see the available parking areas on street where it is permissible and also in different parking areas. Furthermore, the system plays a crucial role in supporting drivers in identifying their cars and locating parking spaces at the appropriate place by verifying availability, assigned slots, non-allocated slots, and also previous reservations in that parking lot. Parking lot availability, reserved spots, open spots, and booking history are all checked to compile this data. The goal of this work is to display the current availability of

parking centers at the appropriate user locations, regardless of whether the parking center is a public parking lot, a building, a small retail center, or a common parking center. Access to this data will be made available to customers, and it will include the vast majority of parking lots in the immediate vicinity of the desired parking place. End customers may check out the available slots, sign up for the system, and book a parking spot all via a web app thanks to this layer. Besides this constraint, the system is also susceptible to the following limitations: In addition, embedded sensors must be installed at the outset of the deployment process in a manner that is consistent with the architecture of the parking lot. If the user has arrived at the location then it will grant the request and book a slot for the user.
Weather reporting systems are primarily used to monitor ever changing climate and weather conditions in overly regulated sectors such as homes, industry, and agriculture. Our model consists of a microcontroller (such as an Arduino UNO or ESP8266) that serves as the system;s central processing unit and to which all sensors and devices (such as humidity and temperature sensors) are connected. Provides data on humidity, temperature, and CO level fluctuations in the precise location where the embedded monitoring device is installed. Our implementation model consists of different sensor devices such as Arduino UNO o Node MCU o LDR light dependent resistance o CO sensor - carbon monoxide (CO) sensor o DHT11 temperature and humidity sensor o Anemometer – used to measure wind speed. Level 1 is the environment, Level 2 sensor devices and sensor data. Characteristics of these sensor devices, characteristics and each sensor device is also operated and controlled based on its sensitivity as a detection area. Level 3, for example, describes data collection from sensor devices and also includes decision making.
The global trend in street lighting is an area that deserves attention in terms of improving the efficiency of power consumption for the purpose of saving energy, as street lighting accounts for 18-38% of total energy consumption. We will use these Sensors to detect any object and will turn on the street light pole at the position and also street lights next to it when any object is detected. For example if a street light pole detects an object at point X it will respond to it and turn the street light at point X ,X+1,X+2 to turn on. The IR transmitter is placed in direct line-of-sight with the IR receiver so that the IR receiver can continuously receive infrared radiation.

Chapter 4

Result and Discussion

4.1 Result

The system may generate reports based on the waste status on E-Bin, as well as a mapping based on the model we suggest. We compared system-generated report data with real test data to assess the accuracy of our system. Using a scale to measure the height of the garbage, we gathered data from the trash can for real-world analysis. In addition, we have used gas to determine if the sensor correctly detects the gas. Then, we constructed the data table for the system and compared it to our real test data.

4.1.1 Test Case:

Initially, the data was taken from the trash. The information shown in Table [4.1] was manually extracted from the bin. We have conducted a random study of data from three users. According to the chart, User Id 12's bin is 10 cm free at its top edge. This indicates that the threshold for bin capacity has been exceeded. Therefore, collection is necessary. User ID 34 has 23 centimetres of unoccupied space above the trash. This indicates that the bin is halfway full when it reaches a height between 15 and 30 centimetres. Therefore, immediate collection is not required. User ID 27 has 53 cm of space available, which does not exceed any threshold limit, yet the bin remains empty anyway. Another test case result is available for User ID 12. We can tell that the trash can is almost full since we measured the distance, which was 12 centimetres, and the threshold limit showed that the trash can was nearly full. 11 to 15 centimetres is the threshold for almost full.
The table [4.2] is a system-generated report that we gathered from the server. This

Table 4.1: Tast Cases And Results:

User ID	Test Case Bin Status	Test Data	Expected Result	Output	Bin Status	Result
12	The dustbin is filled completely	Less than 10cm	Filled	Filled	Full filled	Pass
12	Dustbin is almost full	12cm	Almost Full	Almost Full	Almost Full	Pass
34	Dustbin is half filled	23cm	Not fully filled	Half filled	Half filled	Pass
27	Dustbin is half empty	53cm	Empty	Empty	Empty	Pass

Table 4.2: Bin Status data from server

Date	Time	UserID	Email	Longitude	Latitude	Situation	Time	Worker ID	Phone Number	Vehicle Longitude	Vehicle Latitude	Status height
2022-01-12	2:12 PM	12	rimon@gmail.com	98.7861884255	23.653329078	Almost Full	1:56 PM	56	01736686396	98.7852309238	23.65145097163	Empty height
2022-01-12	2:37 PM	34	semon@gmail.com	98.7709561256	23.673409234	Half Full	2:04 PM	67	01945163820	98.7830967135	23.65004867135	Empty height
2022-01-12	2:51 PM	21	rim2@gmail.com	98.7702394538	23.6718734235	Full	2:25 PM	31	01817470168	98.7953347613	23.67243993415	Empty height

table displays the data supplied by the E-Bin module. In this instance, we have used the ultrasonic sensor reading to determine the bin's state. The system has a threshold limit of 3. First, the threshold limit will be less than or equal to 10 cm if the trash can is full. Second, a new threshold has been established for the condition of bins that are almost full. To indicate that the barrier has been set between 11 and 15 cm. And contact between servers will cease once the 15 centimetre barrier is exceeded.

According to the [4.2] database, the bin status for user id 12 is almost full. Because table[4.1] reveals that the last time data was received by the bin had a current status of 12 centimetres, this suggests that the bin is almost full. However, user ID 12 contains an additional item in the manual data database. Previously, the state of the bin was full. As it has been updated lately, however, the server has the most recent data according to the current date and time. By comparing two tables, we may determine that our test data and system data match. According to the system, the bin state for User ID 34 is half full. We can see from the test case database that the test case is matched, indicating that we passed the test case. We have no data for User ID 27 in the system database because we only transmit data to the server if the threshold limit is empty or almost full.

In this Table[4.2] we can see some more data in every row. This table consist some other information about mapped worker with there ID and location. We can see when we run our algorithm we come up with this table and Table[4.3]. This table just make a mapping with all the user with the same date. Than our algorithm from this table make another mapped table with User ID and assigned worker.

In the first scenario, the process of verifying the state of the bins, we have an accuracy of up to 92%. Since the current status for User ID 12 on the server is set to 12, yet the current status was 11.7 cm when we measured it physically, In other instances, however, the test data was matched with manually testing. Again, when we collected the position of the worker, the GPS module location was 98% correct, but getting the location from the GPS module took a long time.

This is also due to the fact that the GPS module transmits data in NMEA format. NMEA 2000 is a plug-and-play initial signal used to link maritime instruments on board boats. Standard NMEA GPS data format is supported by all GPS manufacturers, including cellular module providers. This data format allows application developers to use their GPS application on a variety of GPS devices. Net to get GPS position information from this NMEA data, resulting in our demise. Again, when we employ geolocation, there is a lag of up to 10 to 15 percent. This indicates that the GPS position obtained via geolocation may be off by 10 to 15 metres. Overall, our system can monitor the state of the trash can with an accuracy of up to 91%.

4.2 Discussion

This table contains the complete data for a specific user request for waste collection and the specified worker with an ID. Our microcontroller transmits information to

Table 4.3: Assigned Worker Table

Date	Time	UserID	Worker	WorkerID	Longitude	Latitude	Time	Phone	Staus
2022-01-12	2:12 PM	12	Jamal	56	98.785230923	23.6514509716	1:56 PM	01736686396	Assigned
2022-01-12	2:37 PM	34	Kamrul	**67**	98.7830967135	23.65004867135	2:04 PM	01945163820	Assigned
2022-01-12	2:51 PM	27	Samim	31	98.7953347613	23.67243993415	2:25 PM	01817470168	Assigned

the server if the trash can's capacity exceeds 85%. Close to capacity for more than 70%. This is visible from our table. We are transmitting data every 30 minutes. And if there are any residual data for that user at the same time, the new data will replace the old data and be stored. In addition, our server is generating this table. After obtaining the prior data, our algorithm will traverse this table as a tree, establish a mapping for user ID to worker, and return the table above.
This table will show us which worker is assigned to collect which user's waste. We can see there is userID also. From the user ID we can get the user details and can track on the worker and the user in real time. We have also published an application for better optimization.
According to the paper [3], RFID has been recommended for the bin in order to keep track of it. From Bangladesh's standpoint, RFID sensors that give each container a unique identifier seem pricey. Bangladesh is a nation with a lower middle income. If we utilise the least expensive RFID in our bin, it will cost between 300 and 400 TK. For the purpose of resolving the issue of bins with unique identifiers, we have implemented a user registration form where data saved in the database will automatically generate a unique identifier for each user, and user login will provide authentication.
Many other systems, including the one suggested in the publication [4],[3], have employed GPS modules to determine the position of the trash can, however standard GPS modules do not function inside. Moreover, this module takes too long to establish a satellite connection. Consequently, this module might result in several disadvantages within In addition, the minimum price of a GPS module is around 800/900 TK. Which is ineffective for a developing nation such as Bangladesh. In order to solve this issue, we devised a contemporary solution: when a user applied to our system, the geolocation API was used to determine the user's location. So that our users may access our system simply from any mobile device or PC. To get a user's location, we must have their consent. This method is not only economical but also much quicker.
According to the [6], they presented a smart bin with sensors such as a hall effect sensor, accelerometer, and ultrasonic sensor, but they did not provide a method for garbage collecting or disposal. In addition, they employed an accelerometer and hall effect sensor to determine whether or not the bin was open. Compared to this, our model not only provides a solution for the waste disposal process and garbage collection, but also checks the bin.
Again in the [13], their approach includes RFID for storing data with a unique ID, and they have put a GPS sensor in the container. However, we have devised a low-cost and simple alternative in substitute of these pricey modules. We have replaced them with a simple user registration form that uses geolocation to determine the location of the bin, which is superior than GPS in an indoor situation. In addition, in their test case table, there are undefined values for the bin's volume since their model is incapable of determining the bin's volume, but our model can accurately

detect the bin's status and transmit data to the server.
We can see in the paper [23] that they have designed a far more efficient smart bin for the smart city. Their model is able to assess the bin's state, make decisions, and provide server-side reports. However, they offered no answer for garbage collection and staff management. Where our model is able to not only check the state of trash bins, but also send a report to the server using an easy-to-implement solution and choose the nearest employee for garbage collection. Also able to assess the physical state of workers from a human standpoint.
In a second article released by BRAC University in 2022, they suggest an intelligent waste management strategy for smart cities. They have created a smart bin with RFID for user identification and information, a GSM module for delivering messages to the collector, and an ultrasonic sensor for determining the state of the bin. According on the bin's state, they send a message to the worker, excluding longitude and latitude coordinates from the location. In a smart city, however, there are not only a few workers who frequently collect trash from a certain location. We need to choose the nearest worker automatically, rather than sending a message to a single worker. In addition, the location was sent manually without longitude and latitude, making it difficult for workers to locate the bin. Our model can verify the state of bins, and our server knows the location of workers in real time. So that every worker may be linked to the server, and when a request arrives into our server, we have the real-time location of the bin along with its longitude and latitude, and our server can execute the shortest route method to identify the nearest worker by using both longitude and latitude. Thus, our suggested model is much more efficient than the proposed model.
Based on article [14], they have created a trash collecting system. They have presented an algorithm for optimising the quickest path in which the route will be updated everyday and workers will get a new route each day. However, they did not provide any solutions for worker selection, waste collection, or waste disposal. Where our model selects the nearest worker and notifies the server appropriately about garbage pickup.

Chapter 5

Conclusion and Future Work

5.1 Conclusion

In conclusion, a smart waste management system is an innovative solution to the growing problem of waste management. By incorporating technology such as sensors, IoT, and data analytics, a smart waste management system can improve the efficiency and effectiveness of waste collection and disposal. This can lead to significant cost savings, reduced environmental impact, and improved public health. However, implementing such a system requires careful planning and collaboration between the government, private industry, and the public. Further research is also needed to develop and refine the technology and to fully understand the potential benefits and challenges of smart waste management systems.

5.2 Future Work

Numerous studies are being conducted to determine the optimal waste management strategy. In our study, we present an Internet of Things-based integrated waste management system that is fully automated and capable of information exchange. Population increase, escalating industrialization, and fast urbanization must wreak havoc on the global ecosystem. We've tried to build a workable model of a smart management system that can handle waste not only smartly but also can take a high load. This system might help to solve the waste problem. Gradually, it is becoming more difficult to exist in densely populated urban areas due to the escalating rate of trash production. Traditional trash management techniques involve failure to properly manage such a large amount of waste. Proper waste management is a core service supplied by municipalities or many organizations dealing with garbage and sustaining a circular economy that supports the health and happiness of citizens and encompasses all waste-related operations from inception to the final disposal. So, future work can be done more not only automating the waste collection from home or industry but also the dump station needs to be automated. The dump station needs to process and dispatch the waste according to the waste category. So, from the very beginning, waste production to disposal and recycling will be in a way that will not only help to develop the smart city life but also save the environment.

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