Solar Powered IOT based Smart Solid Waste Management System

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ABSTRACT

In this paper, we provide a solar-powered, Internet-of-Things-based smart waste management system capable of real-time remote monitoring to ensure the proper collection, transportation, and disposal of rubbish from homes and businesses in any country. Reliable garbage pickup and disposal on a regular basis is essential to maintaining a healthy ecosystem. The primary goal of this research is to create an efficient and effective smart garbage collection and disposal system to maintain a comfortable living environment. The proposed system uses a long-range (LoRa) communication device to enable real-time remote monitoring of multiple solar-powered smart bins spread out across the city and linked to the control station, and an Automated Vehicles Locating System to oversee waste collector activities like collection and disposal time (AVLS). Each site also contains a conventional bin as a backup in case the electronic one breaks down. Solar panels, WSNs, IoTs, cloud computing, and the shortest route finding algorithm are only some of the technologies woven into the fabric of the system's design. Renewable energy source, multiple smart trash bin, SMS notification system, automated vehicles tracking system, web-based real-time monitoring system, and shortest route generation system are the six subsystems that will be created inside this framework. All of these components will eventually work together to form a waste management system that is both effective and efficient in terms of resources used.

Keywords :IOT, smart bin, smart city planning, WSN, E32- TTL-100 LoRa module, AVLS, arduino mega, US sensor, PIR sensor, GSM module, solar power.

1.INTRODUCTION

One of the most critical problems of our day, waste management affects countries of all economic levels. When nations develop economically, they also take on more environmental responsibilities. There are many different types and categories of rubbish, from medical waste to radioactive sludge, from everyday household trash to toxic industrial waste[1-3]. Numerous affluent countries are able to handle and treat waste materials of various forms while developing nations are finding and adopting smart waste management solutions that have enormous real-world advantages. However, developing countries still have significant challenges when it comes to collecting and properly discarding municipal and industrial garbage. Major cities in underdeveloped countries have among of the worst waste management systems and are notorious for littering and illegal dumping[4-6]. Cities like Dhaka, Bangladesh's capital, were in the forefront of the country's rapid urbanisation and industrialization as it developed as a developing nation. An increase in urbanisation in developing countries has transformed the characteristics of solid wastes, and MSW production has skyrocketed over the last decade. Overflowing trash cans and dustbins are a common sight in public places around the country, contributing to both uncleanliness and visual clutter.

It also causes air pollution and spreads a foul odour over the neighbourhood. People may be put at risk of contracting infectious diseases, and the value of the neighbourhood may go down as a result. It is difficult to use existing waste management practises in underdeveloped countries because of factors such as the socioeconomic environment and unexpected infrastructural challenges[7-9]. It costs the government a lot with little return to ensure that garbage is not carried and disposed of improperly, creating an unhealthy and inhospitable environment. Thus, trash must be properly contained, dumped, collected, transported, processed, and reused so that it may be used as a resource for the country. To do this, we proposed a new approach to trash management. A clean, healthy, and green environment may be the consequence of the IoT-based, solar-powered waste management system proposed above. This system would ensure proper garbage collection, real-time remote monitoring, and disposal.

2.RELATED WORKS

Many academics in academia and business have been developing new uses for IoT in smart cities. Taking into consideration the advantages of IOT technologies, they proposed several concepts for efficient waste management in urban areas, and this research provides a short overview of a selection of these works. To improve waste management, the authors of[10] utilised smart city platform technology, but their attention was entirely on data collection. In this research, however, numerous methods have created optimization-based waste management systems. Using LoRa WAN technology and a route optimization strategy, the authors of paper[11] present an Internet of Things-based waste control and management system that is well-suited to rural areas. However, there was a lack of transparency in terms of communication and optimal placement of trash cans. In [12], the authors investigate the most efficient trash collection route designs. This essay, however, is predicated on an IOT cloud solution that merges device connection, data processing, and control rather than the design and optimization of trash collection. In order to maximise efficiency while minimising power consumption, the scientists designed a simple system that can detect when trash cans are full, gather that information, and then transmit it across a wireless mesh network. However, there are certain conceptual flaws with the system that need to be resolved. Closest neighbour search, colony optimization, genetic algorithm, and particle swarm optimization are only a few of the suggested optimization methods for IoT-based waste management provided in[14]. In order to collect garbage, the authors created a system that featured an autonomous line-following vehicle and a robotic hand, but they did not implement any algorithms to optimise the process[15,16]. The authors of[17] suggest a high-tech trash can equipped with a chute specifically designed to service multi-family dwellings. The trash in this system is monitored by a US sensor, and when it gets close to being full, an Arduino Mega acts as a microcontroller and texts a reminder to the garbage man.

In [18], the authors use an 8051 microcontroller to create an Internet of Things-based garbage management system that can detect when a trash can is about to overflow. The transmitter's microprocessor, radio frequency (RF) transmitter, and sensors are all housed in the wastebasket. While an RF receiver, Intel Galileo, and a web browser make up the receiver's core technology stack. Infrared (IR) sensors were used in a microcontroller-based system and the trashcan was connected to a central system through Wi-

Fi, displaying the trash's current status on a mobile web page. Real-time waste statistics for the whole city may be obtained by using a network of sensor-equipped smart bins connected through cellular network, which generates a massive amount of data. For reliable Smart City and M2M solutions, the authors of [21] developed a Smart Waste Management System (SWMS) that is controlled by Internet of Things (IoT) technology and geospatial technology and intelligence sensors like US sensors. The proposed technology might reduce the workload of trash collectors by keeping track of the collection process. The inexpensive camera and infrared (IR) sensors work together to maintain the streets of[22] clean and hygienic. In this post, we set out to find ways to decrease the total cost of trash collection and transportation while simultaneously raising service quality and enhancing people's quality of life.

3.THE PROPOSED SYSTEM

The suggested WSN-based system architecture is shown in Figure 1 and has various pertinent IOT-based Solar-Powered Smart Waste Management System with Real-Time Monitoring- An Advancement for Smart City Planning 2020. 12() G The Global Journal of Computer Science and Technology, Volume XX, Number 5, Version I, Year 2 Included in the 020 subsystems are solar panels, intelligent trash cans, a text message alert system, a web-based real-time monitoring system, automatic vehicle location tracking, and a web-based shortest route-finding system for collectors. The size of a city and the amount of rubbish generated daily in that city decide the total number of smart bins (SB1, SB2,...., SBn, where n is an integer) and waste collectors (WC1, WC2,...., WCn, where n is an integer) operating under a central control station. In Figure 1, we see a city-wide deployment of SBs supported by a network of CBs. Each smart bin in a city also has a traditional trash can nearby in case the electronic one fails. To ensure a garbage-free environment at all times, the conventional bin may be used instead of the smart bin if the smart bin's lid is permanently closed due to technical issues or other causes such as a truck/collector accident, breakdown, lengthy idling, etc. Using WSNs for wireless communication, smart bins gather information from a variety of sensors and then transmit that data and other pertinent details to the control room. The control station not only stores and visually displays data recognised from several smart bins, but also gathers data from these bins. Whenever the trash can is overflowing, the SMS notification system included into each SB transmits an instantaneous alert to the central station, while simultaneously updating the trash can's state on the LCD and activating the smart bin's Red LED. The bin won't be able to be opened until the garbage has been removed. To ensure that collection and disposal chores are completed in a timely way, the control station, upon receiving several SB alert messages, generates a shortest route on the map and sends it to the collector, along with the collecting time. When the garbage can is empty, the smart bin will notify the central station and update its status. It is planned to build a web-based application to monitor and manage the collection and disposal of all smart bins in real time.

4.REQUIREMENT ANALYSIS

The following hardware and software components are used in our works.

a**) Hardware Requirements**

- i. Solar panel, solar controller, battery pack & regulation circuit
- ii. Arduino Mega
- iii. Servo motor with motor driver & metallic gear
- iv. PIR Sensor
- v. US sensor
- vi. LCD
- vii. GSM module with SIM
- viii. E32-TTL-100 LoRa module
- ix. Automated Vehicles Locating System (AVLS)
- x. Robot car kit etc.

b**) Software Requirements**

i. Bootstrap, JavaScript and PHP language-based web application

ii. MySQL based database

iii. Google maps API premier service etc.

5.DESIGN AND IMPLEMENTATION

The planned system is broken up into sections, with each section serving as a hub for various subsystems that will carry out certain functions. The hardware and software components of this system are briefly discussed here. The planned system is broken up into sections, with each section serving as a hub for various subsystems that will carry out certain functions. The hardware and software components of this system are briefly discussed here.

a) Solar Energy System

Regulated electricity is provided to the different components of smart bins by solar energy, the world's cleanest and most plentiful renewable energy source. Connecting the solar panels, the solar charger controller, and the rechargeable battery results in the solar power system shown in Figure 2. The solar panel is designed to convert the energy of the sun directly into electrical current. Overcharging is prevented by the solar charger controller's management of current flowing from the solar array to the storage batteries. Many of the parts and sensor systems in smart bins rely on regulated power from the circuit that controls it.

b) Touch-Free Smart Bin

Figure 3 depicts a trash can utilising wireless sensor network (WSN) technology and an Arduino Mega microcontroller for data collection and processing. The Smart Bin design takes a regular garbage can and upgrades it with sensors that detect when it's becoming full, then uses wireless communication to alert the proper authorities. In this research, touch-free dustbins are used, with passive infrared sensor (PIR) motion sensors measuring waste level and ultrasonic sensor (US) sensors detecting the presence of a human being. There is no need to put your hands in the trash to open the lid since the bin's lid opens automatically when a person walks up to it. The garbage can cover is opened and closed by a servo motor that operates on its own. There is a digital screen inside the bin that shows the current status of the bin. The trash can's fill level is shown on the LCD as either empty, 50% full, or 90% full. There is a Red LED that lights up when the percentage of garbage in the bin exceeds 90 percent, signalling that the bin should not be used until it is completely emptied. The trash can's lid won't release until all the rubbish has gone inside, so nobody can screw it up by dumping trash in there prematurely. A green light indicates that the trash can is empty (0% full) and a yellow light indicates that it is halfway full (50 percent full). Those who do not read the message shown on the LCD may still determine whether or not they should go to a certain trash can to dispose of their trash by looking at the corresponding one of three different coloured LEDs. Fill-level indication scenarios are summarised in Table 1. The E32-TTL-100 is a long-range (LoRa) wireless communication module that connects smart trash cans to the central control hub, where it relays information such as the trash can's unique identifier, its fill level, the current time, and its status. .

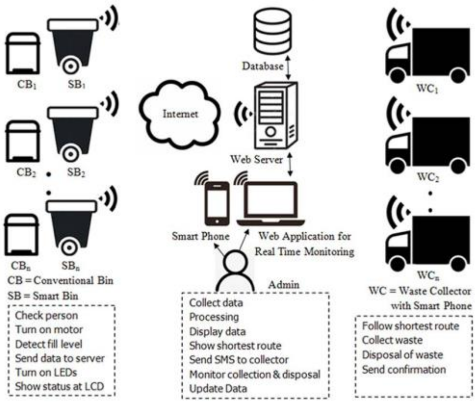

Figure 1: Illustration of an automated smart waste management system framework for the smart city

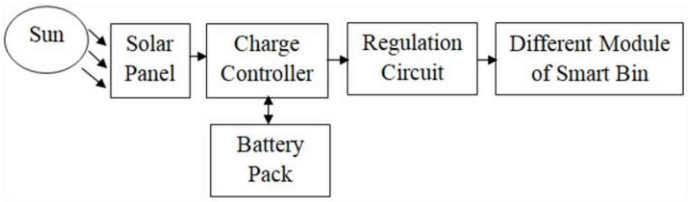

Figure 2: Block diagram of the implemented solar power source

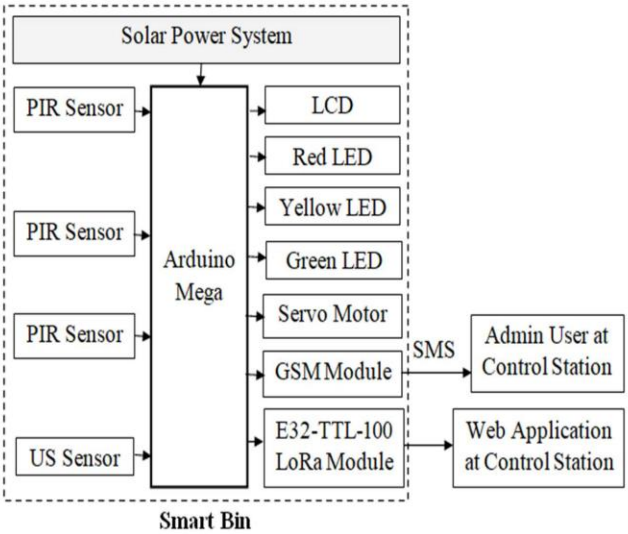

Figure 3: Block diagram of the implemented smart bin

Table 1: Waste bin conditions and fill level indicators

Condition	Threshold	INDICATORS			DESCRIPTION
		LED	LCD	SMS	
1	0%	Green	The bin is empty.Please use it.	Not Sent	Empty
2	≥50%	Yellow	The bin is semi-full.Please use it.	Not Sent	Semi Loaded
3	≥90%	Red	The bin is full.Please use the conventional bin.	Sent	Full Loaded

c) SMS Notification System

When a smart bin is full, it will send an SMS to the central control station with the bin's unique identifier and name. Uncollected trash may be reported by customers using an integrated customer complaints module in the SMS notification system. This work utilises a GSM Modem for SMS notification since it accepts SIM cards from any GSM network provider, can send and receive data over the network, and can be remotely controlled and logged. The RS232 port allows for two-way data transfer, which might be useful for developing embedded software and communicating with other devices. Figure 4 shows a block schematic of the actual SMS notification system.

d) Control Station

The suggested system architecture revolves on the control station, which coordinates all tasks between the various subsystems. The control room is home to the system's core server, which is where you'll find the web server, database, and fastest route-finding algorithm for trash collection. The smart trash cans transmit data to a central control station, which subsequently processes and stores the information in a database server. The responsible authority will be able to check in on the status of the smart bins and order collection and disposal right from their web browser, thanks to the GUI for showing data from the online application for real-time monitoring. To monitor the numerous smart bins and trash trucks in real time, we developed a web application. In this research, we use a computer as a command centre. Using this web application through the Internet, an administrator in the control room or from anywhere may coordinate all of the responsibilities of the many subsystems of our developed system. The results of the developed web app are shown in Figures 8 through 11. This web app's front end is built using HTML, CSS, and Bootstrap, while the back end is built with PHP. MySQL is utilised in this web application for database storage and administration. The web application for real-time monitoring will communicate with the corresponding garbage collector(s) through Google Map API, and the shortest route-finding system will then transfer the unique route map to them. The Google Maps API is a JavaScript interface that makes it easy to include an enhanced version of Google Maps into other websites. Users who have upgraded to Google Maps API Premier may connect through HTTPS. In order to show users where their trash cans are and what condition they are in, this app makes use of the Google Maps API. With the help of the AVLS installed in each vehicle, managers may track the whereabouts of the WCs in real time using a custom web application. The AVLS uses state-of-the-art GPS technology as its foundation.

6.RESULTS AND DISCUSSION

All portions of the proposed system have been built and thoroughly tested. Figures 5–11 depict various views of the prototype and the results of the tests conducted on it. There are a total of five intelligent trash cans spread out across the area. The circuitry of the finished smart bin is shown in Figure 5. All of the modules are linked together by means of the Arduino Mega. Solar panels provide regulated DC electricity for the trash can's various compartments. See Figure 6 to see how the green, yellow, and red LEDs attached to the smart bin light up to indicate whether the bin is empty, halfway full, or completely full. A fill level indicator is also displayed on the LCD screen. Each smart bin will confirm to the control room administrator via SMS that the bin is truly full, as shown in the screenshot from Smart Bin1 (SB1) in Figure 7. In Figure 8, we see a visual representation of the smart bins' fill level measurement in the form of a progressive bar chart. Diagrammatically, we can see that while SB1, SB3, SB4, and SB5 are all at full capacity, SB2 is only halfway full. Information about a particular bin, such as its bin id and location, can be accessed by clicking the View Details icon to the right of the relevant progress bar. When a smart bin's collected data indicates that it is about to reach 90% capacity, the associated web application will issue a filling alert warning on the corresponding map, as shown in figure 9. This results in web-based and short message service (SMS)-based fill level alerts being sent to the control station. Figure 10 depicts how an administrator can generate the most efficient route for trash collectors on a map, which can then be viewed on a mobile device. Two medium-sized robotic vehicle kits equipped with AVLS are used as trash collectors in this research. Figure 11 depicts a possible way for the administrator to shadow the trash collector as they gather trash and dispose of it. As can be seen in the diagram, WC1 is out collecting garbage throughout the shortest route map, while WC2 is tasked with maintaining the vehicles. .

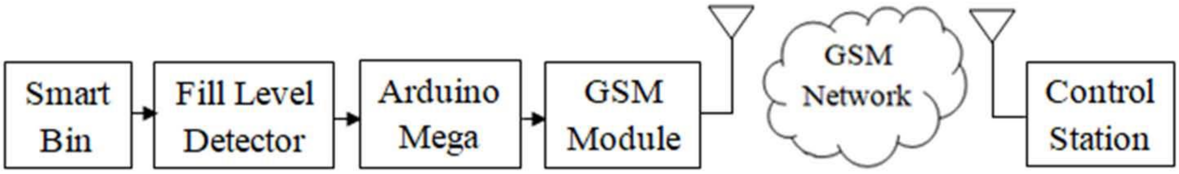

Figure 4: Block diagram of the implemented SMS notification system

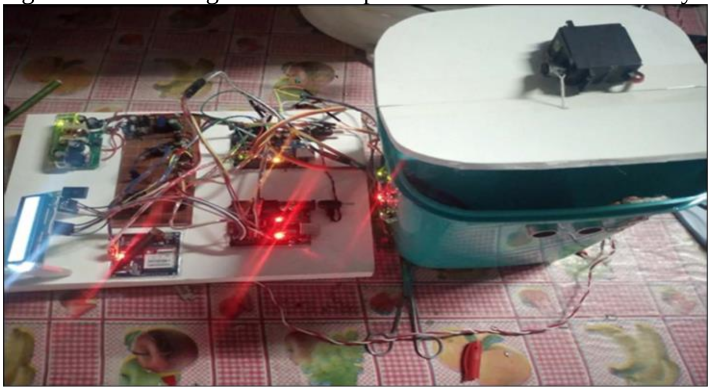

Figure 5: Circuits inside an implemented Smart sBin

(a) (b) (c)

Figure 6: Empty, half loaded and full loaded condition of the smart bin indicated by (a) Green, (b) Yellow, and (c) Red LED respectively

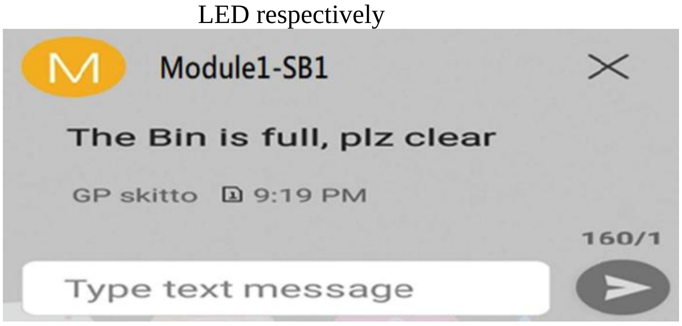

Figure 7: Admin received SMS at control station from Smart Bin1 (SB1) during full loaded condition

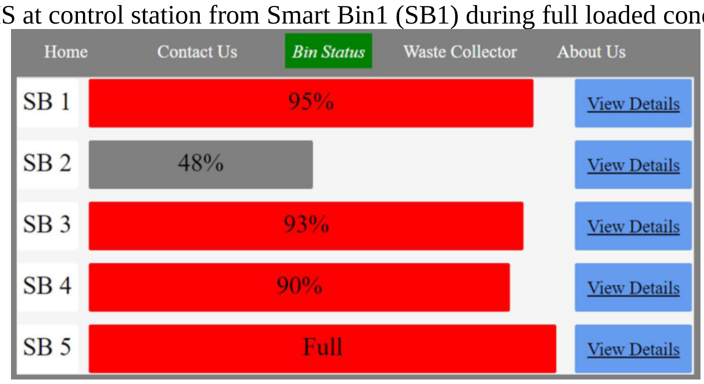

Figure 8: Real time filling level status of the smart bins at the control station

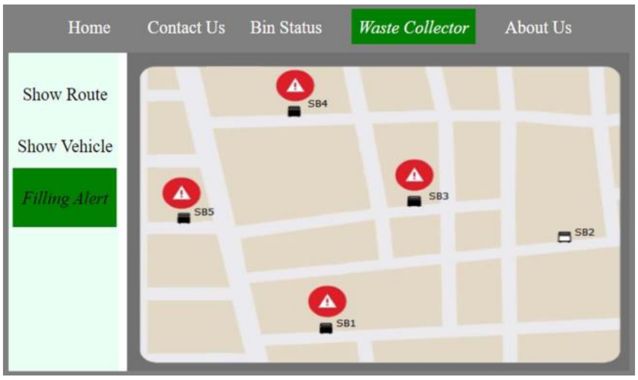

Figure 9: Filling alert notifications from different smart bins at the control station

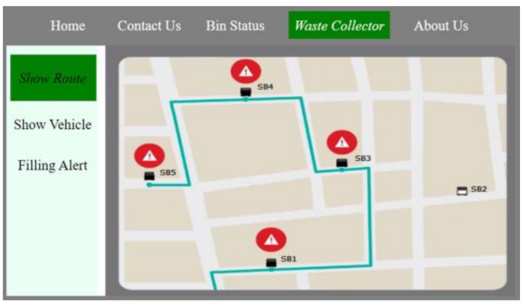

Figure 10: Shortest route map generation for the waste collectors

Figure 11: Real time tracking of collection and disposal activities

7. CONCLUSION

Waste collection and disposal might undergo a radical change thanks to a recently introduced smart trash management system that makes use of the Internet of Things (IoT) and cloud computing to provide automation via cyber-physical systems. Keeping our environment clean and free of filth and debris may be as easy as implementing this proposed strategy, which may be accomplished at a reasonable cost for any municipal and urban places in both developed and developing countries. Residential and commercial spaces are equally amenable to digitalization and modernization using this approach, with the latter potentially yielding smart and environmentally friendly settings that may increase life expectancy. It may be sufficient to deploy smart bins in educational institutions, such as university campuses, hospital districts, giant retail malls, and so on, in order to preserve a healthy atmosphere. Furthermore, when waste and rubbish materials have been properly disposed of at disposal sites, the recycling industry may utilise precision sorting to convert them into valuable resources for our country.

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