Smart Garbage Bin Systems – A Comprehensive Survey

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Abstract. The neat and clean surrounding is the main driving force for any city to be called as "smart city". Many modern cities are currently encumbered with various challenges such as smart transport system, smart grid, smart environment, and smart living. Now-a-days, proper waste management is the major concern for cities and urban areas. The traditional waste management approaches are not sophisticated enough to achieve a proficient and robust waste management. The smart Waste Management is on top priority in any smart city as it directly affects the lifestyle, healthcare and environment. This article deliberates a comprehensive survey of various proposed approaches for smart bin systems such as Smart Garbage Monitoring System, Wisely Waste Segregation System, and Smart Waste Collection System. In addition to this Survey, we propose a framework for smart Garbage Management System (GMS) that can be deployed in metro cities.

Keywords: Smart bin · Cloud computing · IoT · RFID · WSN · Sensors

1 Introduction

Integration of the two eminent technologies, Information and Communication Technology (ITC) and the Internet of Things (IoT) gave birth to the concept of smart city. In order to understand the concept of Smart Cities in depth, a suitable definition is needed. In the literature, various researchers proposed various definitions of smart city. The simplest definition of smart city is that "A city that monitors and integrates conditions of all of its critical infrastructure, including roads, bridges, tunnels, rail/subways, airports, seaports, communications, water, power, and even major building. The City can better optimize its resources & plan its preventive maintenance activities, and monitor security aspects while maximizing services for its citizens [1]". Smart Cities can be identified along with six main dimensions [2], viz.

(1) Smart Economy- Innovation and Competitiveness
(2) Smart Mobility - Infrastructure and Transport
(3) Smart Environment - Resources and Sustainability
(4) Smart People - Creativity and Social Capital
(5) Smart Living - Culture and Quality of Life
(6) Smart Governance -Participation and Empowerment.

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The major smart city applications [3] include Smart Street lighting, Smart Parking, Environmental monitoring, Information Beacons, Active Safety, Smart Journey Planning, Transport Sharing, Smart Bin Collection, Social & Health Care Cost Reduction, and Smart Social Housing.

We cannot imagine a smart city without having smart bin collection and monitoring system because this directly impacts the health of the citizens. Due to various reasons such as migration of people from villages to cities, rapid urbanization and modernization the population of urban areas is increasing rapidly worldwide. According to World Health Organization (WHO)'s Global Health Observatory (GHO) data, the population of urban areas in 2014 accounted for 54% of the total global population, up from 34% in 1960, and continues to grow, and it is estimated that by 2017, even in less-developed countries, a majority of people will be living within urban areas [4]. In urban areas, the Waste Management responsibility is typically carried out by the respective municipal corporations. The authorities of such corporations often instruct the citizen to deposit their household wastage at specific places in garbage bins. Due to the change in consumption habits, life-style of urban population and owing to the increase of population in urban areas, the volume of solid waste to be handled by such corporation is increasing enormously.

According to the World Bank's review report [5], the global Municipal Solid Waste (MSW) generation levels are expected to increase to approximately 2.2 billion tonnes per annum by the year 2025. Therefore, our traditional Waste Management system will be not able to handle such a huge volume of waste generated by cities; so "smart" bins are the need of time. If the municipal or corporation authorities are unable to manage garbage, then the garbage accumulation may become the root cause of illness and diseases such as diarrhea, dengue, etc. Degradation of garbage in open areas also causes bacterial and virus to grow, there by affecting the public health. Due to rapid urbanization, it is noticed that Waste Management became a crucial issue for municipal or corporation authorities as such bodies suffer from limited budgets and resource crunch. Traditional handling of garbage bins typically by human resources alone in large cities such as metros is no more a smart way of handling the Waste Management issues.

Many researchers and organizations conducted research on smart cities. Numerous interesting smart applications have already been implemented such as smart parking, smart transport, weather & environmental monitoring and many more. Among these applications, the smart Waste Management is considered to be a most important and yet challenging one.

We observed enough number of research articles and project implementations based on smart bin collection and monitoring system across the globe. The topic, smart bin gained popularity in last few years (Fig. 1), and the number of projects and research articles shows an increasing trend since 2012.

In this paper, we present a comprehensive survey of research papers in the area of smart monitoring of waste, smart bin collection and route optimization for garbage collection.

The rest of the paper is structured as follows. Section 2 outlines driving technologies of smart Waste Management system. Section 3 gives an overview of the existing and contemporary works in the area of Waste Management in Smart Cities, &

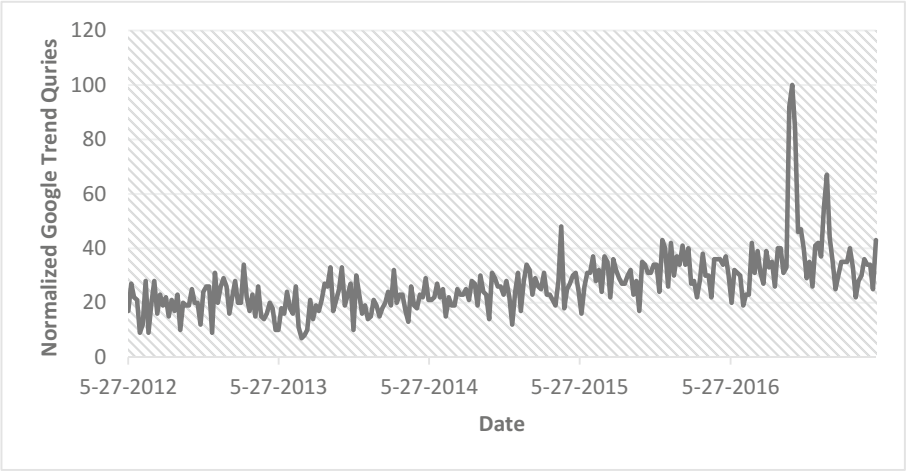


Fig. 1. Interest from Google research trends about smart bin.

Sect. 4 we propose a Framework for Smart Waste Management. Finally the Sect. 5 concludes with a brief summary of observations and for future scope.

2 Technology Support for Enabling Smart Waste Management Systems

Recent available technologies such as Pervasive Computing technologies, the Internet of Things (IoT), Cloud Computing, Big Data, and Wireless Sensor Networks (WSN) provides vast opportunities for researchers and developers to use these technologies the in area of smart bin collection system development. We observed a good number of research work in different aspect of smart garbage management such as smart monitoring of bin [13–27], selection of optimized routes for garbage collection [21–24], waste segregation [28]. Such systems typically use various recent technologies such as IoT [13–20], Integration of IoT and cloud computing [21–24], RFID [17–20], micro controller (Arduino Uno) [13–16], WSN [25–27], and Smart-M3 platform [30] to design and implement the smart bins.

The basic objective of Cloud Computing is to provide applications and services from data centers through the Internet to all over the world. The Cloud Computing provides services as the basis of pay-as-you-go model. The Cloud services include Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Software as a Service (SaaS). Infrastructure as a Service (IaaS) is a model that offers the Infrastructure. These cloud services may be useful for smart waste management system such as cloud storage used for storing real time sensor data, and CPU cycles used for processing of data.

The existing smart bins are equipped with various types of sensors that provides real time data for better management of resources used in waste management system. The Internet of Things refers to an idea of interconnection of uniquely identified physical objects (e.g. our daily usable items such as food, clothing, furniture, paper, etc.) via the Internet and with the help of standard protocols. These objects are typically connected through wireless technology such as Wi-Fi, Bluetooth, etc. On contrary to the objective of networking of computers in the conventional Internet; the IoT aims to provide network of any "things" (including PCs). IoTs have a huge number of potential applications, and these can be grouped into four domain, viz. Transportation and logistics, Healthcare, Smart environment (home, office, plant) and Personnel and social domain [6].

An object (garbage bin) can be attached with Radio-Frequency Identification (RFID) tag [7], which uses radio waves to read and capture information. RFID tags can store information and when compared with identification techniques such as bar code, RFID tag does not need direct line of sight for reading data. The RFID tags are widely used in smart bins for wireless data communication with the sink node.

The many smart bins implementations [13–16] used microcontroller board like Arduino Uno [8] (Uno a Italian word, which means one), Rasperi pi, LaunchPad, Nanode, Pinguino, STM32 Discovery, Teensy 2.0 etc., these boards uses limited power.

The number of interconnected devices (things) is increasing exponentially in last few years, and it is anticipated that the number will reach up to many trillions soon. These devices will generate a large volume of data. Indeed, IoTs will be one of the main sources of Big Data [9].

The IoTs and the Cloud computing technologies both have their own advantages and limitations. The characteristics of these two technologies complement each other when integrated in an application. As depicted in Fig. 2, the IoTs can be a benefit from the virtually unlimited capacities and resources of cloud to compensate its technological constraints (e.g. storage, processing, and communication) and Cloud can benefit from IoTs by extending its scope to deal with real-world things in a more distributed and dynamic manner, and for delivering new services in a large number of real scenarios [10]. The application of this integration are smart home, smart city, healthcare, smart grid etc. The good numbers of researchers [21–24] used this integration in smart waste management system.

A Wireless Sensor Network (WSN) [11] is a wireless network consisting of spatially distributed autonomous devices using sensors to monitor physical or environmental conditions (e.g. temperature, humidity, light, vibration, pressure, etc.) and designed to exchange their data through the network. The sensors connect the physical world with the digital world by monitoring and capturing the real-world conditions and converting these into a digital form. A wireless sensor node is capable of doing in-network analysis along with data collection with the help of on-board processing unit, chip radio and storage units. The WSN is used in various smart bins by many researchers [25–27].

Some of smart bin system is using Smart-M3 platform. Honkola et al. [12] proposed an open-source project called Smart-M3 platform that provides an environment in which different entities can share information and cooperate in a transparent way to the heterogeneities. The Smart-M3 as an information interoperability approach enables the devices to easily share and access local semantic information, while also allowing

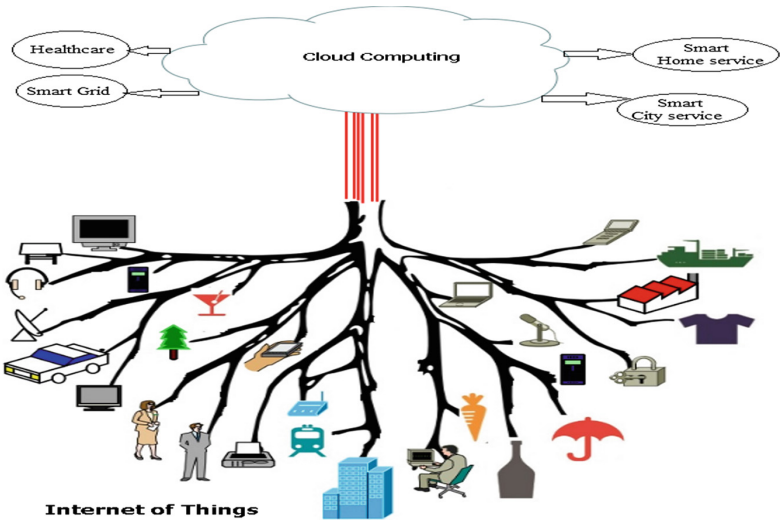


Fig. 2. (M)any thing(s) generate data and the cloud provide services.

access to the locally relevant parts of the "giant global graph" to be available. The information is represented as semantic web, thus allowing easy exchange of global and local information.

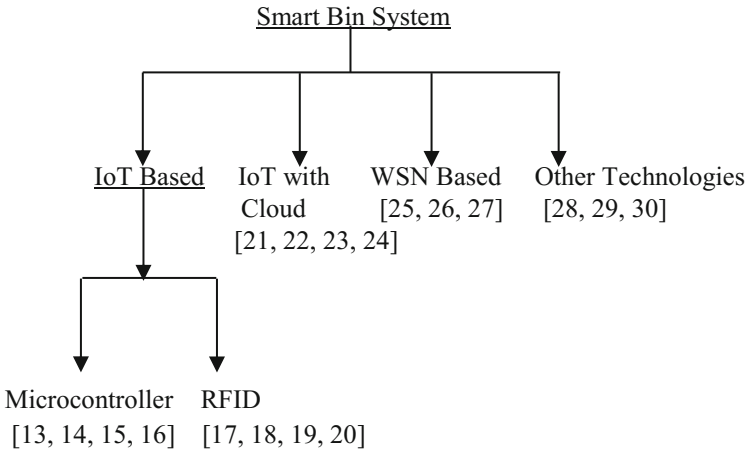
3 SWMS – A Comparative Study

Waste Management is a complex process that involves many steps: it includes generation, on-site handling and storage, collection, transfer, processing and disposal of solid wastes. The overall Waste Management involves three main types of entities:

- Users who generate waste,
- Waste collectors/city admin.
- Stakeholders.

As discussed in the earlier section, a huge number of research and projects have been done on various aspects of Waste Management. Such implemented projects typically use Arduino Uno micro controller based smart real time bin monitoring system [13–16], RFID technologies, Geographic Information Systems (GIS) and Geographic Positioning System (GPS) etc., Relatively all the works attempt to use cloud to access the stored sensor data and further analysis [21–24].

In general, we can classify smart bin system based on the applied technologies as follows:



3.1 IoT Based Approach

Microcontroller Based System

Yusof et al. [13], proposed an Arduino Uno micro controller based smart garbage monitoring system in order to measure the waste level in the garbage bin in real-time and when the garbage level is about to become full, then this system is designed to send an alert via SMS to the municipality so that the bin can be emptied, and garbage collected immediately. The system is equipped with ultrasonic sensor to measure the waste level, the GSM module to send the SMS, and an Arduino Uno which controls the system operation.

Adeyemo et al. [14], developed a smart city technology based architecture for refuse disposal management and implemented a proof of the concept prototype for the architecture. The system is again based on Arduino Uno micro controller board and in addition equipped with proximity sensor, refuse bin and a personal computer. The proximity sensors are attached on the five different position in a refuse bin and interfaced with the Arduino board with capture data set. To determine the appropriate classifier for realizing the pattern classification unit of the prototype, an experiment was performed using the acquired data set to train five different variants of the K-NN classifier.

Kumar et al. [15], developed a smart intelligent garbage alert system based on Arduino Uno interfaced with the ultrasonic sensor and if the garbage is filled, then this system sends the alert to the municipal web server. To perform the remote monitoring of the clearing process, an Android application is developed and linked to a web server to intimate the alerts from the system to the urban office. The notifications are sent by the Android application using Wi-Fi module.

Dugdhe et al. [16], proposed Waste Collection System architecture using the Internet of Things. The objective of this system is to schedule trucks by finding shortest path between the almost filled waste bins and bins, which have produced harmful gases

and gives an optimal route for garbage collection. The architecture consists of an embedded device with sensors and micro controller for sensing information of bins and sends to workstation. The system can also generate reports about waste gathering and fuel consumption for the logistics.

RFID Based System

Chowdhury and Chowdhury [17], proposed a novel Automatic Waste Identity, Weight, and Stolen Bins Identification System (WIWSBIS), which is based on RFID and sensors. Using WIWSBIS, Waste Management service providers (e.g., municipalities, waste collectors) have a chance to track a waste identity (i.e., customer), weight missing/stolen bins quickly and accurately without any human intervention.

Issac and Akshai [18], introduced a system called SVASTHA (a Sanskrit word, which means "be healthy and hygienic"), which is based on RFID and GPS system that can effectively manage the Municipal Solid Waste. This embedded system has been developed to gather data from the RFID reader through Bluetooth's connectivity and upload to a central server.

Wahab et al. [19], presented a smart recycle bin using RFID-based system integrating the web-based information system with the host server. This system works based on information in the smart card which automatically calculates the weight of waste and stores it into the card. This system assists the end user for waste classification and to know the status of smart bin.

RFID based Urban Solid Waste Collection system proposed by Karadimas et al. [20] uses ultrasonic sensors that provide ranging information, which is later translated to fill-level estimations.

3.2 IoT and Cloud Integrated Approach

CloudSWAM, a cloud-based smart Waste Management mechanism [21] lets the sensor based garbage bins to notify its waste level status to the cloud. The stakeholders are able to access the desired data from the cloud and thereby perform route optimization for effective garbage collection.

With the integration of ultrasonic sensors and GPRS techniques, the micro controller based Dynamic Waste Management System [22], could measure the weight and volume of garbage and information sent to cloud server. Ant Colony Optimization (ACO) technique is used to find the shortest possible garbage collection route for each truck. The system is adaptable to dynamic changes, i.e. routes blocked during the waste collection process.

Another cloud computing based Smart Garbage Monitoring System [23] utilizes the concept of a network of smart garbage bins based on the Stack Based Front End approach of integrating WSN with the Cloud computing. To improve the efficiency of the garbage monitoring this approach uses Machine Learning techniques on the collected sensor data.

Use of surveillance systems as an assistive technology for high [24] quality of Service (QoS) in waste collection is proposed by Medvedev et al. Specifically, IoT components, viz. RFID tags, sensors, cameras, and actuators are incorporated into surveillance systems for efficient waste collection. This system consists of an advanced Decision Support System (DSS) for efficient waste collection and incorporates a model

for data sharing between truck drivers on real-time in order to perform waste collection and dynamic route optimization. Surveillance cameras are incorporated for capturing the problematic areas and provide evidence to the authorities concerned.

3.3 Wireless Sensor Network (WSN) Based Approach

Longhi et al. [25], proposed a Solid Waste Management Architecture based on sensor nodes and makes use of Data-Transfer Nodes. This WSN based system is used to control the filling of the bins, collecting data from embedded sensors. Remote monitoring on the web is facilitated as part of this system design. The system incorporates an integrated DSS for effective solid Waste Management by giving optimal solutions.

The Real-Time Solid Waste Bin Monitoring System Framework [26] is based on WSN and contains three levels: smart bin, gateway and control station that stores and analyzes the data for further use. The key objective of this framework is remote monitoring of solid waste bin in real time, via ZigBee-PRO and GPRS, to assist the solid Waste Management process. The waste collection route can be optimized by feeding the collected data into a decision support system.

The Smartbin system proposed by Folianto et al. [27] incorporates the concept of Wireless Mesh Network (WMN) and duty cycle techniques to reduce power consumption and to maximize operational time. The system is designed to collect data and to deliver the data through WMN. The Smartbin system has a three-tier architecture: outdoor nodes, analytics, and workstation. The Smartbin system was implemented and deployed on outdoor test bed.

3.4 Other Technologies

The main objective of GREENBIN [28] is segregation of waste at source so that the individual components of waste can be converted to useful electricity. The use of sensors like capacitive based moisture sensor, inductive based metal sensor, methane sensor and odour sensor helps to achieve this goal.

Thakker and Narayanamoorthi [29], introduced Smart Garbage Bin, which will alarm and inform the authorized person by SMS using GSM technology, when the garbage bin is about to fill. This system is designed to separate five types of plastic resins (which are not biodegradable) from garbage by using Near Infrared (NIR) spectroscopy and provides the details of all biodegradable substance that can be further used in bio gas plant.

Catania and Ventura [30], proposed an approach to smart waste collection based on Smart-M3 platform. The proposed approach can improve and optimize the handling of solid urban waste. The Smart-M3 platform helps solving the issue of interconnection among heterogeneous devices and data sharing involving a large amount of people. The real-time monitoring at the level of bin's fullness is made possible through sensors placed inside the containers. The data gathered is given for a decision system to determine the optimal number of waste vehicles or bins to distribute in the territory.

A comprehensive comparison of various waste management systems in terms of the sensors used, technologies applied and data transfer techniques used is presented in Table 1.

Table 1. Comparison of various existing smart bin system

S. No.	Smart Bin System	Technology Used																
			Sensors used												Data Transfer Techniques			
		Microcontroller	Ultrasonic	Load Cell	RFID	Proximity	Gas Equality	Temp., Humidity	Accelero meter	Moisture, Metal	Methane ,odour	Cloud Tech.	GPS Module	Web Technology	WiFi Module	Bluetooth	GSM/GPRS	Radio or ZigBee
1	Smart Garbage Monitoring System [13]	✓	✓	×	×	×	×	×	×	×	×	×	✓	×	×	×	×	×
2	An architecture for refuse disposal Management [14]	✓	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
3	Smart Garbage Alert System [15]	✓	✓	×	×	×	×	×	×	×	×	×	×	×	✓	×	×	×
4	Waste Collection System architecture [16]	✓	✓	×	×	×	✓	×	×	×	×	×	×	×	✓	×	×	×
5	WIWSBIS [17]	×	×	✓	✓	×	×	×	×	×	×	×	×	×	×	×	×	×
6	SVASTHA [18]	✓	×	×	✓	×	×	×	×	×	×	×	✓	✓	×	✓	×	×
7	Smart Recycle Bin [19]	✓	×	×	✓	×	×	×	×	×	×	×	×	×	×	×	×	×
8	An Intgrated Node [20]	×	×	×	✓	×	×	×	×	×	×	×	×	×	×	×	×	×
9	CloudSWAM [21]	×	✓	×	×	×	×	×	×	×	×	×	×	×	×	✓	×	×
10	Dynamic Waste Management System [22]	✓	✓	✓	×	×	×	×	×	×	×	×	×	×	×	×	✓	×
11	Smart Garbage Monitoring System [23]	✓	✓	×	×	×	×	×	×	×	×	✓	×	×	×	×	×	✓
12	Waste Collection [24]	×	×	✓	✓	×	×	×	×	×	×	×	✓	✓	×	×	×	×
13	Solid Waste Management Architecture [25]	✓	×	×	×	×	×	×	×	×	×	×	✓	×	×	×	✓	×
14	Solid Waste Bin Monitoring System Framework [26]	×	✓	✓	×	×	×	✓	✓	×	×	✓	×	✓	×	×	×	✓
15	Smart Bin System [27]	×	×	×	×	×	×	×	×	×	×	✓	✓	✓	×	×	×	×
16	GREENBIN [28]	×	×	×	×	×	×	×	×	✓	✓	×	×	×	×	×	×	×
17	Smart Garbage Bin [29]	✓	✓	✓	×	×	×	×	×	×	×	×	✓	×	×	×	✓	×
18	Smart Waste Collection [30]	×	×	✓	×	✓	×	×	×	×	×	×	×	×	×	×	×	✓

4 Proposed Framework for Smart Waste Management

To achieve a smart and efficient Waste Management System (WMS), we propose a framework that is capable for smart and smooth management of garbage in the city. Our proposed framework is illustrated in Fig. 3. If initially the garbage segregation is done, then it is easy to manage the garbage that lead to better WMS. The garbage segregation is performed by the citizen with the help of colour coded garbage bins. Basically, three colour coded garbage bins are green, blue and black respectively used for biodegradable waste, plastic & metal waste, and e-waste. The e-waste consists all electronic equipment, which are defective and obsolete like computers, TVs, cell phones, CD players, fax machines, printers etc. The various sensors that may be used in our proposed framework are listed in Table 2.

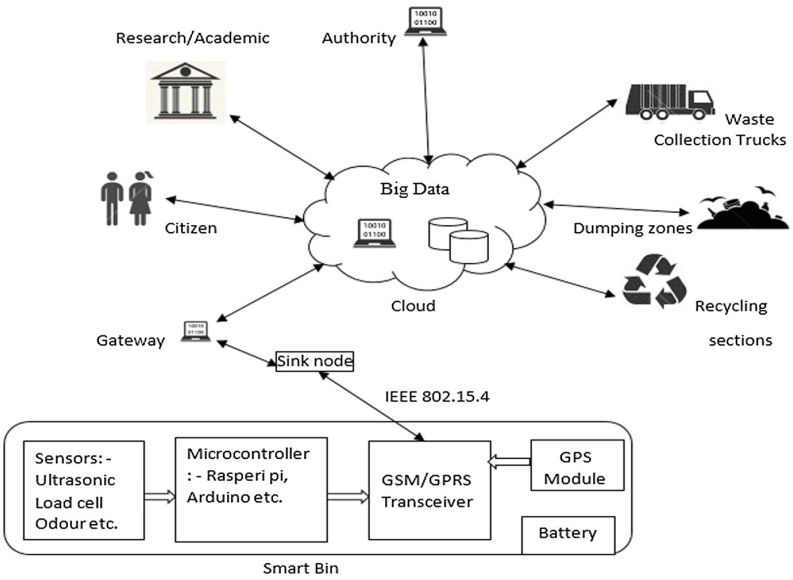


Fig. 3. The proposed framework for smart bin system.

Table 2. The different sensors used in colour coded garbage bins.

	Ultrasonic sensor	Load cell sensor	Proximity sensor	Gas equality sensor	Temp., humidity sensor	Metal sensor	Methane, odour sensor
Green bin	✓	✓	✓	✓	✓	✖	✓
Blue bin	✓	✓	✓	✖	✖	✓	✖
Black bin	✓	✓	✓	✓	✖	✖	✓

The green, blue and black bin may respectively equipped with various sensors that is showed in above Table 2. The sensors like methane, odour, temperature, and humidity is used in green bin because it contains biodegradable waste. The key objectives of these sensors to send alert to authorities, then they can send the garbage collecting vans as soon as possible. The ultrasonic sensor is used to identify the garbage level in garbage bin.

Big Data technologies and tools are used in the framework in order to handle the large volume information stored in the cloud.

This framework also contains GPS module so that their position is geographically identified that lead to make plan for optimal route for garbage collector vehicles across city. The microcontroller monitors operations of various sensors and controls voltage flows among sensors. The output of GPS and GSM/GPRS modules is controlled by microcontroller. The gateway receives data from smart bin with the help of IEEE 802.15.4 protocols such as ZigBee etc. and forward it to cloud storage. The cloud storage uses big data to analyze the huge amount of data and the result will be shared with different stakeholders such as city authority, research institute, dumping section, recycling section etc. This framework also provides a platform for citizen to give their feedback to authorities.

Following is the list of salient features of our proposed framework when compared with that of the existing works discussed in this paper:

i. This framework is suggesting colour coded bin, which is equipped with various types of sensors. With the help of colour coded bin segregation of waste is done at collection point.
ii. Our framework is capable to get real time data from various sensors and uses big data techniques & tools to get optimal result.
iii. The GPS enabled smart bin in our proposed framework indeed helps arriving at optimal and efficient routes for garbage collection.

The following is a list of some, but not exhaustive open research problems applicable this framework:

i. Developing energy efficient protocols at all layers of the network protocol stack such that the battery-powered embedded controllers mounted in the smart bins survive for a reasonable amount of life time.
ii. Provisioning of security features in data collection that are susceptible to various attacks such as false-injection, black-hole and Denial of Service.
iii. Handling the non-cooperative and novice citizens who do not follow the color codes while dumping the waste materials

5 Conclusion and Future Scope

The innovation in technologies via the Internet of things, cloud computing, big data, etc. provides opportunities for researchers to develop the smart bin system to realize “smart cities”. The importance of smart Waste Management cannot be ignored. In this paper, we discussed various enabling technologies and contemporary smart bin systems

with their advantages and limitations. This paper presented a framework that consist the smart bin and Garbage Management System. In future, this framework will be implemented and its performance studied through simulation and test beds.

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