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Waste management issue and solutions using IOT

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Abstract

As population density and rural migration to cities increase, urbanization has a higher proportion and presents an enormous urban problem related to waste generation. Increasing waste generation has been identified as a significant challenge for large urban centers around the world and has been identified as a significant problem for countries with rapid population growth in cities. Cloud computing offers an automation opportunity through the Internet of Things (IoT) and cyber physical systems that change the way solid waste management approaches. Considering the IoT requirements, a review analysis of the waste management models available in the literature will be done in detail in this paper. Then, an in-depth review of the relevant literature will be conducted based on the IoT infrastructure for effective management of waste generated in urban conditions, focusing on interactions between subsidiaries and waste generators (citizens) from a low-cost perspective. As well as citizenship promotion. The IoT-based reference model is described and a comparative analysis of available solutions is presented, highlighting the most relevant perspectives on the topic and identifying open research issues.

Keywords: Internet of Things; Smart City; Smart trash bin; Solid waste management; Waste disposal management

1. Introduction

Waste management means a waste collection system, including its transportation, disposal or recycling. The term is attributed to waste products produced by human activities, which must be maintained to prevent its adverse effects on health and the environment. Mostly, waste is managed to reuse available resources. Waste management practices may vary between developed countries, urban and rural environments, or between industrial and residential areas. Waste management in metropolitan and rural areas is the general responsibility of the municipality, while waste generated by industries is their responsibility and is managed by them.

According to data released by the United Nations Department of Economic and Social Affairs, the share of urban population worldwide is projected to reach 66% by 2050, compared to 52% in 2014, resulting in increased waste generation in cities. Data released by the World Bank Group

Make sure the waste production rate is increasing. In 2012, cities around the world generated approximately 1.3 billion tons of solid waste, producing 1.2 kilograms of waste per person per day. With the rapid population growth along with urbanization, the production of urban waste is expected to increase

By 2025, 2.2 billion tons of municipal solid waste (MSW), a major by-product of urban living, will be growing faster than the rate of urbanization. This increase in the production of municipal and industrial waste promotes the development of applications for better waste management, along with stricter regulations aimed at eliminating illegal waste disposal.

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Other factors that have led to the development of applications designed for effective waste management worldwide are directly related to recycling methods, cycles of technological innovation, use of advanced technologies for waste collection and use of based technologies. Are connected. IoT and big data. There is also a focus on strengthening waste management based on public programs aimed at reducing greenhouse gas emissions as well as creating a more sustainable and safer environment.

According to Allied Market Research, Portland, Oregon [1], waste management worldwide is projected to grow at an annual rate of 6.2% by 2023, with the highest growth in the developing Asia-Pacific region. In Europe, the sector grew by more than 30% in 2016 and is expected to accelerate growth due to high demand from advanced infrastructure and many other sectors.

Currently, government and public officials are taking the initiative regarding waste management to improve the efficient collection and efficient disposal of waste generated by the city. The urbanization and expansion of the industrial sector worldwide is accelerating and the manufacturing and healthcare industries are producing significant amounts of waste and are already being effectively treated by smart management. Can. Furthermore, the growth of infrastructure and the adoption of advanced waste management systems in developing economies with the aim of using cost-effective and waste-time disposal methods should positively impact the development of waste management.

Undoubtedly, the development of the Internet is a major factor in the technological advancements that have led to innovations in the field of waste management [2]. The Internet has revolutionized the world and provides global connectivity. Similarly, the Internet of Things (IoT) [3] is also undergoing significant changes and represents the development of the so-called next generation of the Internet (i.e., the Fourth Industrial Revolution).

Figure 1 Illustration of an Internet of Things (IoT) general framework with several vertical applications

IoT has emerged with a growing number of interconnected physical objects that offer interoperability. The IoT model [4] plays a key role in the integration of various application solutions and communication technologies such as identification and tracking [5,6], sensor networks, wired and wireless actuators [7], and improved communication protocols. And much more. , And distributed intelligence to objects. According to the Internet Business Solutions Group (IBSG), a landmark in the emergence of IoT, the number of Internet-connected objects that occurred in 2008-2009 surpassed the Earth's population. IBSG estimates that by 2020, nearly 50 billion devices will be connected to the Internet [8-11]. IoT has a large number of applications designed to support a wide range of sectors, including industry, transportation, markets, education, agriculture, healthcare, the environment and smart cities (Figure 1) [12-15].

The European Union defines smart cities (SCs) as a system in which people exchange and use energy, materials, services and waste to stimulate economic growth and improve quality of life. These interaction flows are considered prudent because they use the strategic use of infrastructure, services, information and communications in urban management planning as a way to meet the social and economic needs of the community. Despite being a relatively recent concept, the issue of smart cities has already become synonymous with sustainable development in global discussions on sustainability [16]. Currently, cities in developing countries are investing heavily in smart products and services to sustain economic growth and at the same time, developed countries need to upgrade existing urban infrastructure to stay competitive. Among the consequences of classifying A Smart cities can list a wide range of applications, such as waste management based on IoT policies [17-21].

The IoT concept predicts the world in which physical, digital, and virtual objects are interconnected in a network that supports high-order applications. The intelligence of an object comes from the automatic data processing of an existing state or the environmental state in which it is submerged. This data is then transmitted to the processing node and they are analyzed and the appropriate performance profile is determined taking into account the data received from various objects. This activation profile is sent back to the smart object [22]. A waste management system is included in this case because it contains a large number of containers with an inconsistent level of filling, which can be subject to seasonal changes as well as different space requirements such as distance and type. Can. Waste. However, biomedical, chemical and electronic residues have specific collection points, usually with similar production and longer filling periods.

There is considerable difficulty in determining the level of dump filling due to differences in the waste packaging process, i.e. the diversity and clutter of waste materials, which in a way creates unnecessary costs for the municipal collection system [23, 24]. Recognizing the wide range that IoT offers for waste management in the urban environment, this is the focus of this study. This survey is based on cutting-edge analysis of intelligent waste management by IoT. Therefore, the main works of this paper are as follows:

- In-depth review of cutting-edge status on solid waste management;
- Demonstration of structural models for solid waste management identified in the literature based on IoT requirements;
- Identifying open research issues to compare the most promising solutions and suggest further research work on the topic.

The rest of the article is organized as follows. Section 2 provides an overview of the types and methods of solid waste disposal and Section 3 provides insight into solid waste management. Section 4 addresses the IoT architecture reference models available for waste management systems. Section 5 provides a value chain of IoT-based waste management systems and Section 6 describes the most relevant standard protocols used in waste management systems. Discussions and public issues are covered in Section 7, the lessons learned are referenced in Section 8, and finally, Section 9 concludes the paper.

2. Types and Methods of Waste Disposal

Waste generated by different sections of society can be classified according to its composition (physical properties) and destination. This classification is basic because it simplifies the collection, recycling and definition selection of the most convenient target. They load homogeneously with solid waste dumped by urban municipalities, as well as industrial and hospital waste [25]. Currently, selected collection is the cornerstone and goal of proper waste management is the basic approach followed worldwide when recycling. For IoT-based waste management systems, it is important to classify in advance, so specific containers for each type of waste should be considered.

In London, for example, solid waste is collected according to selected collection requirements. It uses different colored containers such as garbage bags or toxic garbage in red; Hospital waste yellow; Hospital waste after disinfection in blue; Black household waste; Glass bottles are divided into groups of green, black and brown depending on their type and color and placed in different containers [26]. Then, the different types of waste are described as follows:

2.1. Organic waste

It is a waste generated from organic waste [27]. They are mainly produced in residences, restaurants and commercial establishments dealing with food. They should be separated from other types of waste as they are mostly destined for municipal landfills.

2.2. Recyclable waste

All of these are wastes used in the conversion process or in the manufacture of raw materials [28]. It is produced in residences, companies and industries and must be segregated so that selected collection teams can collect and distribute it to cooperatives and recycling companies for final processing.

2.3. Industrial waste

They are residues, mainly solids, which are produced in the manufacturing process in industries. It is usually made from leftover raw materials intended for recycling or recycling in the industrial process [29].

2.4. Hospital waste

It wastes generated in hospitals and medical clinics and contaminates and infects people exposed to it [30]. It should be treated according to established criteria with all possible precautions. This type of waste is intended for companies that specialize in treating such waste, where it is usually incinerated.

2.5. Commercial waste

It is made by commercial companies such as clothing stores, toys and accessories. This waste is almost completely recycled [31].

2.6. Green garbage

It is a material mainly produced by cutting down fallen trees, branches, trunks, bark and leaves on roads. Since it is an organic material, it can be used in the manufacture and production of organic fertilizers [32].

2.7. Electronic waste

This means that the waste generated by the disposal of consumer electronics products is no longer functional or obsolete [33]. There are ideal places to dispose, such as companies and cooperatives operating in the recycling area. They send this waste in a way that does no harm to the environment.

2.8. Nuclear waste

It is mainly produced by nuclear plants. It is a highly hazardous waste because it is a radioactive element and must be treated according to strict safety standards [34].

3. Solid waste management

Many published papers cover various aspects of IoT technology for waste management solutions. For example, in reference [35], the authors demonstrate a solution that allows them to plan garbage collection through intelligent monitoring. Through the SMART-M3 platform (an extension of cross-domain search for triple-based information), it is possible to bring great flexibility in interoperating and implementing applications from different domains of information and communication. The solution is developed in two stages: the first is the monitoring phase, where waste levels within the compartments are constantly measured, sent and stored; the second step.

The information collected in it is calculated and applied to optimize waste collection routes. In Reference [36], the authors address the dynamic waste management model through a set of infrastructure services for smart cities based on IoT. With the use of sensors, radio frequency (RFID) and actuators in the detection monitoring process, the set is divided into three stages: (i) waste planning and implementation collection using solutions for routing trucks with dynamic optimization of routes according to limits; (ii) transportation to a specific location depending on the type of waste; and (iii) recycling of recyclable waste. However, it was first used in the first case related to waste planning and collection. The term dynamic refers to the ability of a system to adapt in real time to parameters and schemes that are of interest to waste collection during activity. These tasks provide an overview of the waste management infrastructure, prioritizing the efficiency of the sensors implemented for monitoring and the processes applicable to waste management without recording the communication methods used. [37] The authors offer a solution known as Cloud Based Smart Waste Management (Cloud SWAM). It solves a solution with specific containers for each type of waste (organic, plastic, bottles and metal) with sensors that constantly monitor and update their status in the cloud, where shareholders can obtain information of their interest. Connected to receive. This system works not only in waste management, but also in determining the best collection route to identify a more economical route in the metropolis. In addition, in context [38], a new management model has been introduced that specifically focuses on the search for better areas to build landfills. As landfills are being used as the final destination for commercial and industrial waste, there are concerns about the economy, the environment and public health, so special attention needs to be paid to locating them in large urban areas. Should be concerned. The solution uses information gathered through a language-linked waste management system that uses a genetic algorithm to assist in selecting land suitable for the construction of landfills. In the reference [39], the authors describe the various methods of waste disposal that can be implemented in waste management. They offer a comprehensive solution of a fill level sensor with solar powered waste compression called a smart box, which optimizes waste collection. The information is transferred via wireless communication to the server in the cloud and applies to any type and size of container, and shareholders can log into the server and access the data in real time through smart box monitoring. Among these solutions, the authors noted that the real problem facing large companies is the need for subsidies to reduce collection costs for disposal in landfills, to provide information on interest waste, and to reduce transportation costs. Provide targeted approach. Cities represent the waste management that is mostly generated. In addition, the proposed structure is not well classified.

Intelligent waste management has been demonstrated in this context as a model for improving waste collection [40]. In some countries, such as Australia, municipalities usually charge a fee for waste generated in the city and usually measure the weight of waste for each neighborhood or street and then estimate the average consumer per household. This collection model is not highly accurate and as the cost of disposing of waste increases each year, waste generators (users of the system) demand a cost-cutting solution and run at a fixed rate. Changes the form of charging. Wise waste management can solve this problem by ensuring that the consumer is taxed only on the basis of the waste generated. Additionally, the system can reduce costs with a large number of lost or stolen containers. The work presented here addresses a good proposition when the lack of waste collection only affects the budget of the citizens, but the structure used is not well classified.

A review of the literature on waste collection and optimization of vehicle routing is presented in the reference [41]. To dispel this notion, the problem of multi-constrained and multi-compartmental routing has been proposed, which refers to the results of different collection with lower collection cost by modeling using container scheduling strategies in the decision-making process. Find the best routing strategies, which will ensure that progress in optimization strategies can provide intelligent and environmentally sound solutions. Furthermore, the study presented in the reference [42] proposed an intelligent system of waste recycling. Waste preparation is required before disposal.

Glass in brown containers, paper and aluminum containers in blue containers and plastic products in orange containers. The system automatically estimates the type and amount of waste and benefits in the form of points credited to the card. Simulating virtual currency, the collected points can be exchanged for something or withdrawn through the banking network. The above authors follow the baseline of simple containers for waste preparation, where the first model focuses on the benefits provided by the diverse collection and the second case focuses on providing rewards to citizens who dispose of their waste properly. However they did not explain how the sensors got stuck in the solution.

Reference [43] proposes a solution to the problem of dumps that do not clean up in a timely manner and lead to overflow. The system provides an alarm-triggering monitor and notifies authorized that the container is ready to be connected, through a near-infrared spectroscopy (NIR) screening system that detects five types of plastic resins. And the remaining biodegradable waste is allocated to biogas production. [44] The authors provide a template for collecting information on waste use and help determine if dumpers need additional dumps for a specific area or for disposal elsewhere. Give them where they are needed. With the worst information on a daily basis, cleaning operators can plan better when sending their cleaning crews to empty boxes and even setting routes for their cleaning trucks. In reference [45], a "smart bin" solution is provided, where bins are distributed on the streets with a unique ID. Sometimes, when the container is about to be filled, a query is sent to the database to find out who is responsible for that compartment and a Global System for Mobile Communications (GSM) notification is sent with the container ID and location. The submitted models cover the perspective of the intelligent dump, but in all these models, the sensor component is not very clear, as only one communication model is described.

[46] The authors demonstrated the shortcomings of existing systems compared to the method they proposed. The proposal is based on the Arduino IDE and the 8051 microcontroller, which reads, processes and communicates data from an infrared sensor used to measure the depth of waste inside a controller, transmitting it to the Intel Galileo central system based on the microcontroller. The proposal submitted by these authors interacts well with the sensors and communications used in the solution. They have another model based on the Better Collection Route.

References [47] Review the literature review and comparison of different approaches to smart waste management. It focuses on IoT taking into account its features (detection, sensing, communication, computing, semantics and services) and its features (anything that communicates, detects anything and interacts with anything).

Algorithmic instruction for decision making during waste collection is presented in [48]. Some algorithm models have been compared, taking into account several performance metrics such as speed in receiving data, multiplicity, data loss during transmission, and increased data reception. Not all algorithms that can retrieve data in motion can serve multiple purposes or tolerate increased data reception, but none of them can fix data loss. . Based on this information, some case studies have been proposed and some objectives will be considered such as reducing pollution through timely collection, reducing maintenance costs, using trucks of appropriate size and using the collection route. The algorithm should take into account the speed and the amount of data input as well as the data generated by the same sensor. Therefore, an algorithmic model to optimize collection decisions is proposed in this work. In addition, in reference [49], the proposed model uses information obtained from coaches to define effective routes for each truck during collection. In the model, some constraints are considered as the Poison Distribution model showing the maximum bin capacity and waste arrival rate. When the dump filling limit is reached, the garbage collection alarm is triggered and sent to the base station, which communicates with the cloud to process the data and find the best collection path. Finally, the trucks move to a vacant lot, where the volume of dumps seen is verified and the optimal route of collection is established with the aim of optimizing based on the lowest cost for garbage collection. The solution provides a waste management approach based on three estimates, taking into account the nearest vehicle

First, collection based on the upper bound, and collection based on the upper and lower boundaries. MATLAB has been used to solve Java based simulators for optimization models and heuristic methods based on cost and delay. The proposals submitted by the authors are particularly relevant to search algorithms for the optimal way of waste collection with a focus on reducing collection time and cost. In the reference [50], the municipal waste management system for household use is demonstrated, focusing on the application of biological and physico-chemical methods that can eliminate or significantly reduce the waste collection and transportation phase.

A summary of the comparative evaluation of the most promising solutions conducted in this survey is presented in Section A total of fifteen research efforts are reviewed and their strengths and weaknesses are analyzed and each model is classified to represent important components of the proposed systems. IoT architecture reference models are available for Waste Management Systems

To validate this IoT segment or column, it is important to be supported by the Reference Architecture model, so that in the future, these so-called waste management tools in IoT may be connected (and the Interoperability Challenge will be resolved). She goes).

The Internet is supported by the Transmission Control Protocol / Internet Protocol (TCP / IP) architecture, which enables communication between network hosts. Similarly, IoT-based applications also require architecture, which always addresses issues such as scalability, interoperability, reliability, and service quality (QoS). [51] According to the author, several models and reference architectures are available. Each group or company has its own policies for IoT, which often lead to conflicts of opinion and further complicate the authentication task.

Among the key reference models, it is possible to mention some programs such as RAMI 4.0, the reference architecture for intelligent factories implemented on IoT standards, which began in Germany and later became relevant in the direction of large industrial sector companies. Another initiative was initiated by AT&T, Cisco, General Electric, the International Business Machines Corporation (IBM) and Intel, a consortium of so-called Industrial Internet Reference Architecture (IIRA), which provides a broad discussion and reference structure. The Internet of Things Architecture (IoT-A) is an initiative that promotes an architectural design that describes detailed system requirements [52].

Many project models focus on a specific structure on a few layers that make up the basic model of requirements analysis or reference architecture. Figure 2 shows the basic layered structure. The most basic approach considers only the three-layer structure of the application, network, and perception layers [10]. In the recent literature, there have been other models that add more abstraction to IoT architecture, such as the Service Oriented Architecture (SOA) model, the middleware model [51,53,54] and the five-tier model [11]. , 55, 56].

Even with a flexible structure, there are still relevant challenges, especially those related to security and privacy. Therefore, to meet these challenges, new standard structures should be proposed focusing on important issues such as QoS, stability, data integrity, privacy and reliability. Next, there is a brief discussion about these layers, which alternate between the submitted models.

3.1. Awareness layer

The IoT architecture perception layer is similar to the physical layer of the Open Systems Interconnection (OSI) model because it is based on the hardware layer and is responsible for collecting, processing and securely transferring physical information to the upper layers. Communication. Channel. In addition to collecting object recognition data such as quick response codes (QR codes) and RFID, it implements technologies that detect physical properties parameters through specific sensors such as weight, temperature, and humidity.

3.2. Network layer

The network layer is responsible for transferring the measured information in the perception layer to the upper layers where the processing systems are located. And uses ZigBee, Z-Wire, GSM, UMTS, Wi-Fi, Infrared, 6LWWPAN. In addition to the basic assignments, the network layer also handles the cloud computing process and data management process.

3.3. Middleware layer

The middleware layer is a layer of software or a set of sublayers used to connect parts of the IoT to each other, otherwise the communicator is unable to communicate. In addition to providing synchronization to ensure that the application layer interacts with the perception layer and ensures effective communication, it plays an important role in the development of new technologies.

3.4. Application layer

The application layer does not directly contribute to the creation of the IoT architecture, but within this layer itself various services are built to interface with users, i.e. where information description and availability take place.

3.5. Business layer

This layer is responsible for maintaining the entire IoT system, including providing high-level analysis reports of the underlying layers, as well as service-related applications such as resolving user privacy. This layer is responsible for creating graphs and business models.

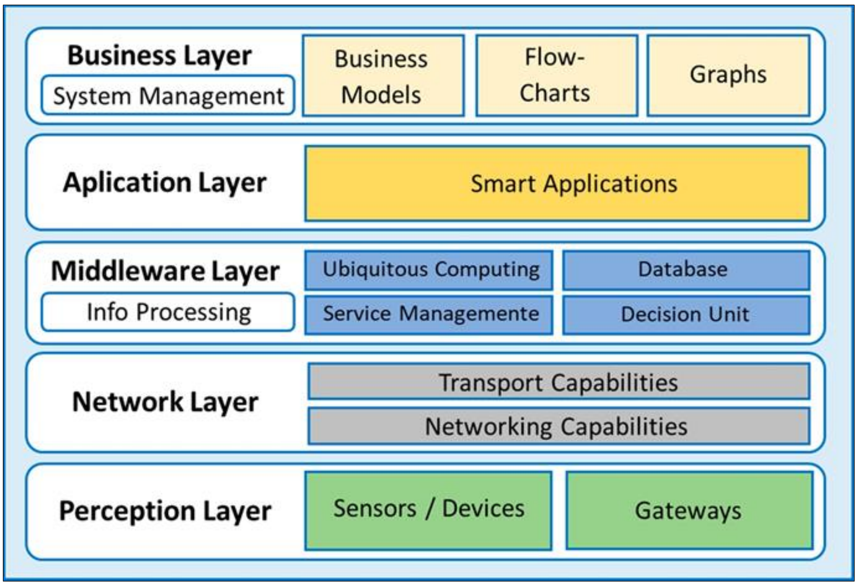

Figure 2 layered architecture of waste management

As IoT connects everything to exchange information, the traffic and stores on the network will increase exponentially. Therefore, IoT application development is based on technology development and design following the reference model of IoT architecture.

4. Value chain of IoT-based waste management system

Understanding the integration of multiple powerful technologies into a single system (such as data acquisition and network transmission) provides a better insight into the meaning of each functionality in the context of IoT [57]. This section presents an overview of how these technologies play an important role in IoT-based solid waste management systems. The set of activities by the identification of each compartment is related to the start of its cycle. It is associated with useful sensing and can accurately display service level conditions with adequate level of communication and provide the minimum requirements required for the proper functioning of the system. In addition, an applied calculation has been added to break down the information that can meet the needs of the large amount of customers accessed through the general services and to access the information to a meaningful representation by an object. Will be easy.

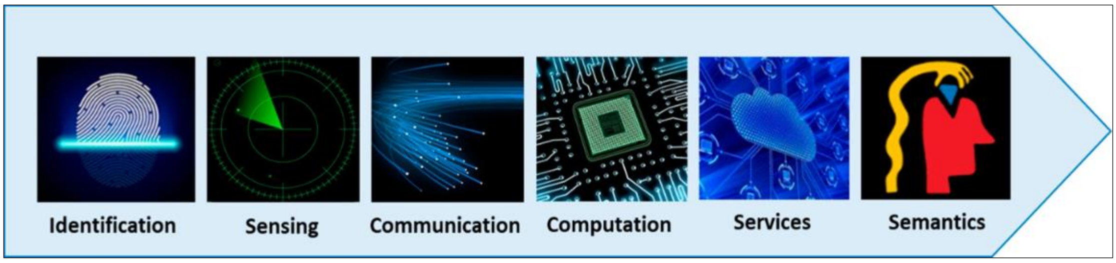

Figure 3 Illustrates this value chain for IoT-based waste management systems

As may be seen in Figure3, the proposed value-chain for IoT-based waste management systems considers the following aspects that are described as follows:

As can be seen in Figure 3, the proposed value-chain for IoT-based waste management systems takes into account the following

4.1. Identity

For IoT, it is important to classify services and link them to demand, so IoT supports various identification methods such as electronic product code (EPC) and universal code (uCode) [58] and GPS trackers [58]. 59], which determines the exact location. The key gives you the ID and address to identify a specific object in the telecommunications network. The ID refers to the object name, for example, "P1" for the specific pressure sensor and its address to the number that identifies the device in the network. Object nesting methods on IoT networks may include Internet Protocol version 4 and version 6 (IPv4 and IPv6). IPv6 (6LoWPAN) [60] provides a compression mechanism over the header on low power personal networks. The public IP address is used as a method of locating objects on the network.

4.1.1. Sensing

Sensing is the process of capturing specific and relevant data from objects in a network and sending it to a database or cloud so that they can be analyzed and used as a basis for decision making in a particular service. Sensors can be classified as intelligent [61], actuators [62] or sensitive portable devices. Many IoT solutions connect devices (e.g., Arduino Yun, Raspberry PI, Beagle **** Black) sensors to single board computers (SBCs) that communicate with application software in central management to provide clients with the information they need. Joins.

4.1.2. Communications

Implementing communication technologies such as Wi-Fi [63], Bluetooth [64], and the Institute of Electrical and Electronic Engineers (IEEE) 802.15.4 [51] is required to integrate various products and provide specific services in the IoT environment.], Lora [65], Wave Z, GSM / GPRS, Broadband Code Division Multiple Access (WCDMA), Long Term Evolution (LTE) and Advanced LTE [66, 67], Near Field Communication (NFC) [68], Ultra- Wideband (UWB) [69] and 6LOWPAN [60,70], and IoT nodes should operate at low power consumption. RFID [71] is a specific communication technology that is also considered when the query signal is released from the RFID reader against the label TAG, which reflects back to the reader. There are different types of TAGs; Battery-powered TAGs; Passive TAGs that operate without the presence of a battery for power supply; And semi-passive TAGs, when required, use a supplied board [72]. NFC technology operates in the high-frequency band of 13.56 MHz up to 10 cm at a distance of 424 kbps [60]. UWB, also known as 802.15.3, is a communication technology designed by IEEE to work in areas with low coverage and bandwidth requirements. [69]. Wi-Fi uses radio waves for communication within 100 meters and allows devices to communicate through a temporary configuration [63], i.e. without the use of a router. Bluetooth is a widely used communication technology for communication between short distance devices. It uses basic radio waves with low wavelengths to guarantee savings in battery usage [64]. 802.15.4, developed by IEEE, provides specifications for both the physical layer and the medium access control layer on low-power wireless networks by promoting reliable and scalable communications [73]. Long Term Evolution (LTE) is a standard for wireless communication that allows high-speed data transfer between mobile phones based on GSM / UMTS network technologies and high-speed mobile devices.

In addition to providing multicast based services and broadcasts [66]. LTE Advanced (LTE-A) is a better version of traditional LTE and has better performance with broadband coverage, spatial multiplexing, higher coverage and shorter latency [67]. The development of WCDMA (3G) and GSM / GPSR (2G) is known as the fourth generation of mobile communications.

4.1.3. Calculation

It is a unit that measures the computational efficiency of IoT based on software and applications. There are extensive hardware development platforms for IoT application activities; Some examples: Arduino [74], UDOO [75], FriendlyARM [76], Intel Galileo [77], Raspberry PI [78], Gadgeteer [79], Beagle **** [80], Cubbyboard [81], Z1 [82], WiSense [83], Mulle [84], and T-Mot Sky [85], but operating systems are considered important because they run during system execution. Contiki RTOS is widely used in IoT scenarios [89, 90] for IoT environments, along with TinyOS [86], LiteOS [87], and RiotOS [88], which provide a lightweight operating system. It is possible to cite. Cloud platforms are another important computing component in IoT solutions. These platforms provide the ability to access data for processing or storage of intelligent objects so that in the future, users can benefit from the knowledge of the data collected. Due to the diverse data and systems integration, data analysis platforms are important in IoT due to the distinctive features of these types of solutions. Similarly, IoT-based solid waste management deals with real-time data that requires correlation and sharing. To meet these needs in a system with a large number of connected devices that generate data through different needs, it is necessary to adopt cloud computing that requires storage, processing and connection capacity to meet the growing demand for data analysis.

4.1.4. Services

Within IoT, services can be classified into four classes: identity services that are the most basic and representation of other services — applications that are required to move objects from the real world to the virtual. That is, they must first identify them; Information aggregation services are responsible for capturing raw information to be processed and disclosed.

5. Standard protocols used in waste management systems

IoT requires a variety of protocols to address the full range of functions, such as sensor data collection, communication protocols, and so on. IoT is supported by various working groups such as the Institute of Electrical and Electronic Engineers (IEEE), the Internet Engineering Task Force (IETF), the World Wide Web Consortium (W3C), the EPCglobal and the European Telecommunications Standards Institute (ETSI). Began to include efforts. For IoT-based waste management solutions, it is not necessary to include all the protocols described below, but they represent the main and most commonly used protocols in the IoT context. A brief description of their main activities is displayed on each layer: Application, Service Discovery and Network Infrastructure Protocols.

5.1. Application Layer Protocols

At the application level, the protocol is used for end-user communication and is usually integrated into middleware solutions for IoT [92]. End-user applications detect the system, ie they can communicate directly with the bottom layers of the protocol stack, such as web servers that are widely used in system integration and communication between different applications.

5.1.1. Compulsory Application Protocol (COAP)

COAP is an application layer protocol developed to support applications on IoT systems [93,94]. Based on the functionality of Representative State Transfer (REST) via HTTP [95], REST is a transport protocol used to transfer data between clients and servers on networks with fewer power nodes, mobile applications, and social networks. Can move in a more direct manner. , Along with the cache connection protocol. Unlike REST, CoAP is associated with the Datagram Protocol (UDP), which makes it an easier and more convenient protocol for IoT applications, including HTTP for lower power consumption when operating on links in the presence of noise and packet loss. Activities are optimized.

5.1.2. Message Q Telemetry Transport (MQTT)

MQTT [96] is a published and signed transport protocol based on the TCP / IP server-client architecture, developed for connections between embedded applications and middleware. It is compatible with IoT systems, using one-to-one, one-to-many, and many-to-many routing mechanisms that provide flexibility and simplified deployment. MQTT has a fixed 2-byte header that is suitable for devices with limited resources such as low-bandwidth connections, battery leaks or unreliable links, and IoT requirements.

5.1.3. Extensible Messaging Presence Protocol (XMPP)

XMPP is an instant messaging protocol over the Internet, independent of the operating system, designed for chat, voice and video calls and telepresence [97]. It supports interoperability with authentication, access control, privacy metering, encryption and other protocols. Text-based XMPP communication using XML establishes overload for a system fixed with XML stream compression using XI [98] and context-based [99].

5.1.4. Advanced Massage Queuing Protocol (AMQP)

AMPQ [100] is an open-standard IoT connection layer protocol implemented in a message-based environment with publishing and signature structure. It supports reliable communication through Primitive, which guarantees delivery, but requires a reliable shipping protocol such as TCP. It is interface interface with communication based message transfer and other protocols with queues, which uses SWAP to send messages to the appropriate queues.

5.1.5. Data Delivery Service (DDS)

DDS [101] is a subscription and publishing protocol developed for machine-to-machine (M2M) real-time communication. Unlike AMPQ and MQTT, DDS has a decentralized architecture and does not require the presence of a broker. It uses multicast as a guaranteed traffic delivery and excellent QoS, supporting up to 23 queues with different communication parameters such as security, instantaneous, priority, durability and reliability.

5.2. Service discovery protocol

Because of the need to ensure the optimal performance of applications developed for a large number of connected devices and IoT-based systems, a resource management approach is required for excellent coverage of the technology. Therefore, the system can find resources and register services automatically. The most popular protocols for meeting these requirements are Domain Name System (DNS), Multicast (mDNS) and DNS Service Discovery (DNS-SD). Current research studies aim to adopt lighter versions of the IoT environment.

5.2.1. Multicast DNS (mDNS)

mDNS is a very simple protocol and uses the DNS namespace locally, which is the only option that does not require manual configuration for Internet devices or the administration of equipment and infrastructure. Ability to operate with or without failures. The name query is handled via multicast messages, in which the client requests an Internet Protocol (IP) address for a specific name for all domain nodes. At that point, everyone on the network updates the cache with a given address [102].

5.2.2. DNS Service Discovery (DNS-SD)

DNS-based Discovery Service (DNS-SD) handles customer-required service delivery functions through mDNS, assisting in locating customers

Desired services using standard DNS messages. Unlike MDNS, DNS-SD does not require a nomenclature configuration [103] and DNS packets are sent via the UDP Transport Protocol, which contains the destination multicast address. The first step in finding the required services is to find the corresponding IP address of the respective host, and then the pairing function is also sent via multicast, which contains the required details for the connection in the form of the IP / port pair of the connected host, as the context names are kept constant, which increases the reliability.

5.3. Infrastructure Protocol

Infrastructure protocols provide communication between devices and networks, i.e. they depend on the connectivity between different types of systems and devices, which can use different data types and spread over considerable distances. Therefore, the Internet is the connecting option between them.

5.3.1. Routing Protocol

Routing Protocol for Low Power Loss Networks (RPL). RPL [104,105] was developed to support minimum routing requirements, always taking into account strong topology, when the network is experiencing an environment where noise or package loss can have a major impact. It guarantees the delivery of traffic from the most critical traffic such as point-to-multipoint and multipoint-to-point. The core of RPL is represented by the target-based acyclic graph (DODAG), where there is only one way and network nodes know their parent and set one fundamentally (the fastest way to increase performance). Unnecessary ways can occur, but the child is unaware of the fragile relationships. To keep the topology and its routing information up to date, RPL uses control messages such as the DODAG information object (DIO) used to determine the distance between each node in the network. Is done for. Routes based on specific metrics to select the preferred parent route. Destination Notice (DAO) is another type of message that provides information about traffic to receive data. The third type of message is DODAG information requests (DIS), which are used by nodes to receive DIO messages from adjacent nodes that are accessible. The last type of message is DAO Confirmation (DAO-ACK), which is a response to a DAO message sent from the DAO target to the DAO parent or DoDAG route [106].

5.3.2. Network Adaptation Layer Protocol

6 Lopan Wireless Personal Area Networks (WPANs) differ from older link layer technologies such as limited packet size (127 bytes for IEEE 802.15.4). The IEEE 802.15.4 specifications require the creation of an optimization layer that matches the IPv6 header length, this difference in packet length to ensure low bandwidth. The IETF 6LoWPAN Working Group developed the 6LoWPAN (Low Power Personal Network IPv6) standard, which specifies the required mapping by IPv6 on WPANs [107] and to meet the IPv6 maximum transmission unit requirement to reduce transmission overhead and fragmentation. Provides compression for IPv6 headers. MTU) and support routing through a network that delivers multiple jumps. 6LoWPAN significantly reduces IPv6 overhead so that a smaller datagram is better transmitted through the 802.15.4 frame packet and shrinks the IPv6 header to two bytes [108].

5.3.3. Link Layer Protocol

IEEE 802.15.4. This protocol specifies the physical layer (PHY) and medium access control (MAC) sublayer on a low-rate wireless private area network (LR-WPAN) [29]. It is widely used in IoT, M2M and WSN due to its specifications (low cost, low power, low data rate), as well as providing reliable communication with a high level of security, encryption and certification for a large number of networks. IEEE 802.15.4 Standard Network Topology, which is star, peer-to-peer,Mesh, and tree format. Star topology usually consists of the Total Function Device (FFD) that serves as the master of the PAN network and is located in the center of the topology and is intended to control all other nodes and other reduced function devices (RFDs). The topology consists of a point-to-point FFD and the other nodes communicate with each other or through intermediate nodes. Tree topology is a special case of point-to-point topology and includes FFD and general nodes [51].

5.3.4. Physical Layer Protocol

Bluetooth Low Power (BLE). Compared to previous versions, the Bluetooth Smart uses short-range radios up to 100 meters, which guarantees ten times longer and 15 times slower delay than the classic Bluetooth [109]. It operates with low power consumption at medium transmission power 0.01 mW and 10 mW, which prolongs the useful life of the device by years and makes BLE a suitable suitor for IoT applications [110], transmitting power per bit rather than zigzag [111]. BLE allows star topology with master tools or writes with a discovery mechanism based on sending messages from slaves to the master via a special advertising channel, after which the master checks to complete the invention. Except when both devices are exchanging data, they are in standby mode.

5.3.5. Electronic Product Code (EPC)

EPC is a technical identification where the personal identification number is stored in an RFID tag used in supply chain management to identify goods [112]. The RFID system is divided into two main parts, the radio signal transponder (tag) and the tag reader. This tag uses the object identification storage chip and antenna to allow communication with the reader using the radio waves reflected in the tag, and then reads specific computer information called the Object Name Service (ONS). OEPC is considered a good technology for the future of IoT applications due to its openness, scalability, interoperability and reliability [113].

5.3.6. Global System for Mobile Communications / General Packet Radio Services (GSM / GPRS)

The GSM network is the first generation of mobile communication systems. Initially, they were developed for voice transmission, but later they started supporting data transmission through some time slots at a low rate of 9.6 kbit / s on uplink and downlink. Following the technological advancement of GSM, HSCSD, the data rate increased and reached

14.4 kbit / s on the uplink and 43.2 kbit / s on the downlink. GPMS has been available to GSM users since GSM version 97 and has enabled the use of data services such as Internet browsing, WAP access, and SMS / MMS, but uses the GPRS packet-switched mode, unlike the previous version. And shares the same stream. Channel only when data needs to be resolved. The data rates available in GPRS are based on the supported multislot class, which can reach up to 21.4 kbit / s with a maximum of 8 downlink or uplink slots [114].

5.3.7. Wideband Code Division Multiple Access (WCDMA)

WCDMA is designed to provide high-speed, packet-switched data services, allowing more efficient use of spectrum that provides high transmission rates up to 2 Mbit / s. Supports access to Internet-based services such as WCDMA fixed-line services. However, WCDMA is defined as second generation backward compatibility requirements [115].

5.3.8. Long-term growth-advanced (LTE-A)

LTE-A is a set of communication protocols that are well-suited for machine-type communication (MTC) infrastructure, in addition to IoT, especially for smart cities, machine-to-machine communication that requires human intervention. Where long-term sustainability is not expected, infrastructure is expected [116]. LTE-A surpasses other cellular mobile communication solutions in terms of cost and scalability of service and divides the structure into two parts, the first of which takes into account mobile devices called Control Network (CN). And treats IP packets. Second, the Radio Access Network (RAN) deals with wireless communication via radio and sets up user planning and control protocols. RAN uses base stations (advanced nodes) connected to the interface, called X2, because the connection to RAN is made through the interface as S1 is called C1. Can be connected to mobile devices or MTC base stations.

5.3.9. Directly or through the MTCG gateway

They may have direct communication with other MTC devices.With the upgrade of communication infrastructure to 5G, the currently available technologies will be incorporated into the concept, i.e. 5G will guarantee specific requirements. For example, some applications require less network latency, others require higher bandwidth, and there are others that require connectivity due to lower amounts of communication, such as IoT-based applications. Given these requirements for IoT applications and existing legacy networks in use, NB-IoT and eMTC networks should maintain this demand until applications are fully available for use as communication infrastructure for applications.

6. Open Issues and challenges

The comparative evaluation of this study is summarized in Tables 1–3, with research efforts on waste management using IoT, with a special focus on dumps and waste bins receiving IoT infrastructure. Information is generated by

Table 1 Physical infrastructure comparison considering the most relevant solutions available in the literature

Ref.	Ins Type	Bins Location	Pneumatic Pipes	Recycling Points	Processing Points
[35]	Glass; Plastic; Paper; General Waste	Outdoor	Disregard	Not Supported	Not Supported
[36]	Organic; Glass; Plastic; Paper; Metal; Toxic	Outdoor; Underground	Incorporated	Supported	Supported
[37]	Organic; Glass; Plastic; Paper; Metal	Outdoor	Disregard	Supported	Not Supported
[38]	General Waste	Outdoor	Disregard	Not Supported	Not Supported
[39]	General Waste	Outdoor	Incorporated	Not Supported	Not Supported
[40]	General Waste	Outdoor	Disregard	Not Supported	Not Supported
[41]	Glass; Plastic; Paper; Metal	Outdoor	Disregard	Supported	Not Supported
[42]	Glass; Plastic; Paper; Metal	Outdoor	Disregard	Supported	Not Supported
[43]	Plastic	Outdoor	Disregard	Supported	Not Supported
[44]	General Waste	Outdoor	Disregard	Not Supported	Not Supported
[45]	General Waste	Outdoor	Disregard	Not Supported	Not Supported
[46]	General Waste	Outdoor	Disregard	Not Supported	Not Supported
[47]	General Waste	Outdoor	Disregard	Not Supported	Not Supported
[48]	Not Specified	Not Specified	Not Specified	Not Specified	Not Specified
[49]	Not Specified	Not Specified	Not Specified	Not Specified	Not Specified

Table 1 relates to the physical infrastructure of the waste bin such as the types of waste supported by the container (organic, glass, plastic, paper, metal, non-toxic or general selection waste); Compartment position (indoor or outdoor); An air hose that automatically compresses the waste to reduce the volume; And recycling and processing points to return waste as raw material or process it for proper disposal. Through the study provided, each model was classified based on the impotence components presented in each system. In relation to physical infrastructure, in both models, waste bins are considered for organic waste; Of the five models, trash cans to dispose of glass; Waste bins in six models for disposal of plastics; Of the five models, dustbins for discarding paper; Of the four models, waste bins for metal disposal; Waste bins for the disposal of toxic waste, in a single sample; And in eight models, common waste. In just one model, the dump can be placed outdoors and underground; among others, only externally. Pneumatic tubes are included in two models, with five models taking into account recycling points and supporting organic waste processing points in a single model.

Table 2 with IoT technologies takes into account the following: RFID support; Sensor type used (capacity, weight, temperature, humidity, chemical, pressure); Automatic actuators (prevent excessive deposits); The cameras are placed to overlap the sensor function; Global Positioning System (GPS); And IoT architecture (solution not mentioned and implicitly stated or solution developed and defined). RFID is embedded in five models, twelve models have a capacity sensor, And weighs at three, but the temperature, humidity, chemistry and pressure sensors are all on the same model.

Table 2 IoT Technology comparison for the most relevant solutions available in the literature (Table1)

Ref.	RFID	Sensors	Actuators	Camera	GPS	Architecture
[35]	Disregard	Capacity; Weight	Disregard	Disregard	Disregard	Implied
[36]	Incorporated	Capacity; Weight; Temperature; Humidity; Chemical; Pressure	Incorporated	Disregard	Incorporated	Defined
[37]	Disregard	Capacity	Disregard	Disregard	Disregard	Implied
[38]	Disregard	none	Disregard	Disregard	Disregard	Defined
[39]	Disregard	Capacity	Disregard	Disregard	Disregard	Implied
[40]	Incorporated	Capacity	Disregard	Disregard	Disregard	Defined
[41]	Incorporated	Capacity	Disregard	Disregard	Disregard	Defined
[42]	Incorporated	Capacity	Disregard	Disregard	Disregard	Defined
[43]	Disregard	Capacity; Weight	Disregard	Disregard	Incorporated	Defined
[44]	Disregard	Capacity	Disregard	Disregard	Incorporated	Defined
[45]	Disregard	Capacity	Disregard	Disregard	Disregard	Defined
[46]	Disregard	Capacity	Disregard	Disregard	Disregard	Defined
[47]	Incorporated	Capacity	Disregard	Disregard	Disregard	Defined
[48]	Not Specified	Not Specified	Not Specified	Not Specified	Not Specified	Not Specified
[49]	Not Specified	Not Specified	Not Specified	Not Specified	Not Specified	Not Specified

To conclude, Table 3 deals with software analysis, i.e. how information is used. It can follow a dynamic collection scheme; Dynamic path of collection; And an experimental evaluation (simulator or actual) for each research effort. In the software analysis category, five models are considered for dynamic programming and dynamic routing is also present in all five models, although the actual experimental data is only received on one model, with all other models using simulators.

Of all the papers analyzed from the physical infrastructure, many authors propose a waste management model through IoT, preferring the collection and scheduling model with dynamic routing for high impact of collection using low energy consumption. Other authors focus on specific bins for each type of waste that promote customers' chosen disposal method; There are also models that offer bonuses to the user based on recyclable waste and models that question user-specific green waste points based on the mobile app. There are also authors who propose recycling and processing points unrelated to this research. In the general case, the focus of all models is on the collection system.

Considering the elements of IoT technology, some authors have the worst bin recognition by RFID and others do not need it when considering GPS, but some models follow GPS technology. We will. The variation of the sensor types in most models is not well recognized, which can lead to false positives if the waste disposal is small in size and overweight. Automatic actuators are not required, as not all types of discs are actually compressed. The fact that the cameras installed in the compartment are ignored when using the appropriate sensor model. The structure of a waste management system is clearly defined as part of the overall design of the system based on a standard or implicit design.

One of the most important aspects of solid waste management that is being studied today is waste collection. This research effort makes a lot of sense when it fails to reflect that 80% of the cost spent on waste management is used in the complex of trucks that travel to cities every day, collecting the waste that people leave behind. [117], a position that expresses a reasonable basis for practicing the procurement process, with convenient ways to indicate significant savings in the time and money achieved by any improvement.

Table 3 Experimental analysis comparison for the most relevant solutions available in the literature (Table1)

Ref.	Dynamic Scheduling	Dynamic Routing	Experimental Data
[35]	Not defined	Not defined	Simulator
[36]	Defined	Defined	Simulator
[37]	Defined	Defined	Simulator
[38]	Not defined	Not defined	Simulator
[39]	Defined	Defined	Simulator
[40]	Not defined	Not defined	Simulator
[41]	Not defined	Not defined	Simulator
[42]	Not defined	Not defined	Simulator
[43]	Not defined	Not defined	Simulator
[44]	Not defined	Not defined	Real
[45]	Defined	Defined	Simulator
[46]	Defined	Defined	Simulator
[47]	Not defined	Not defined	Simulator
[48]	Defined	Defined	Simulator
[49]	Defined	Defined	Simulator

Numerous studies aimed at optimizing routes for solid waste collection have often linked them to the street vendor problem [118] (one of the most studied optimization problems), defined as vendor, which has to go through many cities only once. And return to your hometown by driving a short distance course. Hackers can design a system that computes better collection paths as a problem and this problem is solved by a precise algorithm, an algorithm that always finds the right solution to the optimization problem. Or heuristic algorithms sometimes produce worse solutions. This major challenge of solid waste management systems is the opportunity to study and propose robust algorithms that can solve the adversarial problems presented by IoT-based systems. Among these disadvantages, the main factors to be considered are large amounts of data, the speed at which such data can be received, data variation and data loss during transmission. Implementing data analysis from multiple sources (in the order of terabytes or being able to reach petabytes, which are high speeds and often with losses during transmission) can take a long time to reach. And the solid waste management system has no useful parameter or even impossibility for some algorithms. Furthermore, in Reference [119], the authors propose an algorithmic-based tool model with automated learning "machine learning" to identify capacity measurements that can help make decisions based on public information. Does.

Among the major algorithms available in the literature are the following: backtracking search algorithms [120], ArcGIS [121], heuristics [122], and particle swarm optimization [123]. Recently, a study was published in Reference [48] where the comparison of these algorithms is demonstrated by adding an expectation algorithm model to the waste collection process. It takes into account the receipt of moving data. Getting data in motion is a lot different than getting it statistically. This paper concludes the study by proposing a guideline for the development of an intelligent multi-objective approach based on a weighted sum algorithm to convert it into a single target model through a priori and loss-measure capabilities.

The human factor is another important factor to consider in designing solid waste management solutions, as smart bins are used in parks, stadiums and public places for parties, religious events, concerts, sporting events and extensive spaces. Demonstrations usually take place. Groups of individuals are largely characterized by a variety of physical and socioeconomic and cultural characteristics that exhibit different behaviors when large numbers of people are organized. This study is applied in many cases by simulation to understand their behavior in a large group and to establish parameters and turn them into heuristics, which helps in making decisions and assessing certain situations, mainly called fear. When in withdrawal. In reference [124], a study based on modeling agents applicable to all individuals in an urban area and in a group is implemented through dynamic multisimulation. It is dynamic

Assessing behavior when in large groups of individuals is important in the concept of solid waste management.

Another important factor to consider in a waste management system is the battery consumption generated by the use of equipment / sensors available in the solution. IoT nodes used in solid waste management include ultrasonic sensors and load cells [125], GPS [126], actuators [36], microcontrollers [127] and transmission modules [128]. Some studies illustrate the use of renewable energy by photovoltaic panels for batteries

Analysis of the relevant literature identified overt issues that could be addressed in subsequent research work. They are considered improvements to the proposed systems and are identified as follows:

The waste management platform, which focuses on the policy of citizens interacting with the system through a mobile application, finds bins near their homes by their location, with a relevant level of usage. Upon learning of this information, the customer may choose to place the waste in an available container at that time or keep it intact and wait until the collection system empties the deposit. In this way, consumers are helped to avoid filling the containers and their waste is exposed in the open. The solution consists of a physical compartment (bin) with sensors that constantly sense both the volume and weight of the residue inside. The sensor is operated by the Integrated Development Environment (IDE) microcontroller, which also controls communication via a coupled module. The data is transmitted in the middleware, where it is stored and made available to the mobile application [131].

In the future the waste management system will solve the shortcut to the collection routes, i.e. the trucks will already set off along a route to search for the containers that need to be emptied. In this way, it is possible to achieve a better collection effect in less time and with less fuel consumption. There are many studies available in the literature .It offers a variety of solutions for short paths in collection paths. The waste management platform, which focuses on the perspective of citizens, offers huge benefits to smart cities, along with the resolution of the best collection route as described above.

The waste management system can be integrated with future parking management studies for vehicle parking. Containers can be used as a gateway for parking sensors, which already have an integrated transmission system and provide information to customers through an application that tracks the path from the vehicle's actual location to the available parking space. Recognizes. With built-in waste management infrastructure, it is possible to add new applications to the base system. Parking management using Infrared Presence Sensors based on standard IEEE 802.15.4 with Intelligent Dump is a good example of transmitting data into a single integrated middleware and subsequently made available to customers via a mobile platform.

Another aspect that will focus on future work is an in-depth study on the life cycle of rechargeable batteries used in waste management systems. Since these batteries are stable in containers and have favorable weather conditions for a long time, the cell's performance and its interaction with the environment should be evaluated, as well as its maintenance and protection against temperature rise. Should have done. Due to the spread. In this context, this study did not target applications based on smart cities, but the development of new generation batteries will benefit many applications and significantly contribute to the development of projects in science and technology.

6.1. Lesson Learned

As learned, some aspects of the topic addressed can be considered and shared with the community. It is not possible to solve the problem of garbage collection only by using the waste management system, the excessive collection of waste by the citizens at inappropriate times, or the lack of timely collection by the competent authorities. People need to be made aware and use citizenship to avoid disposing of waste at inappropriate times (for the public, the most important thing is the location of the nearest environmental point with available resources and the closest to the disposable environmental point). It is important that the conglomerates responsible for public procurement always meet the demand in a timely manner, replacing the current procurement system with a methodology based on demand on a weekly schedule basis, i.e. mapping the areas with the most critical requirements.

Another factor related to the final cost of the solution when estimating on a municipal scale. To avoid the economic feasibility of the solution, it is necessary to create ways to capitalize the resources to invest directly in the solution to meet the needs of municipalities with minimal investment. A good example is Visual Advertising, which can be incorporated directly into smart containers or through non-invasive advertising submitted in a mobile application that is fully integrated into garbage management solutions.

7. Conclusion

To transform traditional cities into smart cities, waste management will be a key factor in sustainability, public spending efficiency, improving urban mobility and conserving natural resources. The recent literature has been revised to examine the different features and aspects of intelligent waste management systems using the Internet of Things. Since the expansion of IoT infrastructure can offer many possibilities, first, the major innovation objectives have been identified and some useful application models on the topic of waste management have been described. Through a detailed literature review, solutions to identified problems are described, data detection, transmission, analysis and processing of collected data are considered and the final result for an effective management solution for solid waste is obtained. Using IoT, it is possible to track the location of waste containers, monitor the level of accumulated waste, identify areas with the highest demand, and suggest the shortest way to optimize solid waste collection, or interface with citizens to promote settlement at such times. The container can receive garbage, which promotes civilization and avoids significant problems caused by the accumulation of waste outside the garbage collector.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest.

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