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Deliverable 2.1
System design and preliminary specifications
SAV

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Abstract

System design and preliminary specifications of the smart container to be developed in the PlastiCircle project are described in this deliverable. The state of the art in similar approaches in the smart management of the waste collection as user identification, sensors, data transmission or reading systems were analysed. The stakeholders and regulations are taken into account for the design of the smart container. The actual collection systems of the pilot cities are analysed in order to adapt the design of the smart container to their existing waste collection systems and requirements. The preliminary design of the smart container includes the different elements and modules. Finally, the list of materials of the PlastiCircle collection and system are described.

Abbreviations

DtD: Door-to-door

GHG: greenhouse gas emissions

ICT: information and communication technologies

LPWAN: Low Power Wide Area Network

NFC: Near field communication

M2M: Machine to Machine

MSW: Municipal Solid Waste

PAYT: Pay as you throw

RFID: Radio Frequency Identification

RVMs: Recycling Vending Machines

UNB: ultra-narrow band technology

WPAN: Wireless Personal Area Network

Partners short names

1. ITENE: INSTITUTO TECNOLÓGICO DEL EMBALAJE, TRANSPORTE Y LOGÍSTICA
2. SINTEF: STIFTELSEN SINTEF
3. RTT: RTT STEINERT GMBH
4. AXION : AXION RECYCLING
5. CRF : CENTRO RICERCHE FIAT
6. UTRECHT : GEMEENTE UTRECHT
7. INNDEA : FUNDACION DE LA COMUNITAT VALENCIANA PARA LA PROMOCION ESTRATEGICA EL DESARROLLO Y LA INNOVACION URBANA
8. ALBA: PRIMARIA MUNICIPIULUI ALBA IULIA
9. MOV: MESTNA OBCINA VELENJE
10. SAV: SOCIEDAD ANONIMA AGRICULTORES DE LAVEGA DE VALENCIA Spain
11. POLARIS: POLARIS M HOLDING
12. INTERVAL: INDUSTRIAS TERMOPLÁSTICAS VALENCIANAS
13. ARMACELL: ARMACELL Benelux S.A.
14. DERBIGUM: DERBIGUM N.V.
15. PROPLAST : CONSORZIO PER LA PROMOZIONE DELLA CULTURA PLASTICA PROPLAST
16. HAHN: HAHN PLASTICS Ltd.
17. ECOEMBES: ECOEMBALAJES ESPAÑA S.A.
18. KIMbcn : FUNDACIÓ KNOWLEDGE INNOVATION MARKET BARCELONA
19. PLAST-EU: PLASTICSEUROPE
20. ICLEI: ICLEI EUROPASEKRETARIAT GMBH

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Publishable summary

Nowadays, the internet has become omnipresent in our everyday life.

The deployment and use of technologies allows all types of real-time data manipulation, leading to a smart management in all sectors. The information and communication technology (ICT) has become an inevitable part of the planning and design of modern MSW management systems, making these technologies a potential tool for the optimization of these services. This has led to the idea of implementing the concept of Smart City.

PlastiCircle aims to develop and implement a holistic process to increase packaging waste recycling rates in Europe. This will allow plastic waste to be reprocessed in the same value chain. The project focuses on innovation in the different stages associated with the treatment of plastic packaging waste and specifically on: collection (to increase the amount of packaging collected), transport (to reduce the costs of recovered plastic), sorting (to increase the quality of recovered plastic), and recovery in value-added products.

This document will focus on the system design and preliminary specifications of the smart container to be developed in this PlastiCircle project. First, a state of the art was developed, with a smart management approach. It describes the waste collection in terms of user identification, sensors, data transmission or reading systems. The stakeholders and regulations are also taken into account for the design. The actual collection systems of the pilot cities are analysed in order to adapt the design of the smart container to their existing waste collection systems and requirements. Finally, the preliminary design of the smart container includes the different elements and modules, and the list of materials and a draft of the PlastiCircle collection system are described.

Introduction

Difficulties and challenges in the management of the municipal solid waste (MSW) are continuously increasing due to the concentration of the population in the cities and the increase in the ratio of waste generation due to economic and demographic growth. Thereby, the global production of MSW is about1.3 billion tonnes/year i.e. 1.2 kg/capita/day. Ten years ago, waste generation rate was about 0.64 kg/capita/day[1].

On the other hand, the economic batch destined by the public entities to the waste management is a growing concern for the organisms that must put in action plans of economic sustainability.

In addition to the economic cost, the collecting of MSW contributes to greenhouse gas emissions (GHG), mainly in the cities. This requires to optimize the amount of waste collected per area and minimize the routing distance, in order to increase energy saving and to reduce pollutant emissions. To achieve this goal, information and communication technologies (ICT) have become an inevitable part to plan and design modern MSW management systems. This has led to the idea of implementing the concept of Smart City as an option full of advantages to face this challenge. Among them, it is important to highlight the savings of resources through the optimization of services.

The deployment and use of these technologies allows real-time data acquisition, identification and geolocation of elements, information storage and analysis of information, in order to achieve "intelligent" management.

Today, sensors are everywhere. It is estimated that there are more than 5000 million connected devices, there are sensors in our vehicles, in our smartphones, in factories that control greenhouse gas emissions, in car parks and even in the soil to monitor soil conditions in plants.

This would not have been possible without the great technological boom that has been experienced in recent years in telecommunications. Internet is present practically in all areas. This allows data-sending technology to be more feasible allowing to monitor in real time any variable and to create predictive models through the big data stored.

The massive deployment of sensors is due to the following factors[2]:

Miniaturization facilitates that anything can be connected practically from anywhere.

The improvement of the mobile phone infrastructure

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[1] M. A. Hannan, Md. Abdulla Al Mamun, Aini Hussain, Hassan Basri, R.A. Begum, A review of technologies and their usage in solid waste monitoring and management systems: Issues and challenges, Waste Management, Volume 43, September 2015, Pages 509-523, ISSN 0956-053X

[2] G. Feller, P. Horn, P. Gaudiano et al. El Internet de las cosas en un mundo conectado de objetos inteligentes. 2011 Fundación de la Innovación Bankinter

The proliferation of applications and services that put into use the great amount of information generated from IoT (internet of things)

The importance of optimizing waste collection can be understood looking at numbers: for each tonne of waste transported and collected 5.87 litres of fuel are consumed which emits 4.40 kg of greenhouse gases[3].

With the use of ultrasonic sensors in the containers it is possible to obtain the actual filling situation of the waste containers in any situation, which allows planning the emptying routes.

The term "internet of things" was created by Kevin Ashton in 1999 starting from the M2M communication (Machine to Machine) communication[4]. IoT represents billions of objects that connect to each other in a universal way, no matter what type of M2M solution is used. In addition, devices are not limited only to send information, in IoT information is processed and actions are taken with the help of software solutions. IoT is generally associated with the common vision of connection systems between objects, where using sensors, all the physical infrastructure uses information and communication technologies with the objective of monitoring and managing more efficiently the processes and resources.

On the other hand, Directive 2004/35/EC on environmental responsibility in relation to the prevention and repair of environmental damage, establishes standards that are based on the "polluter pays" principle. This allows public entities to launch so-called "incentive rates" on the management of urban waste. These rates include a fixed part that covers operating expenses and another variable directly related to the quantity and / or quality of the waste produced. It is called "incentive" because it encourages the user to behave in an environmentally sustainable manner in terms of waste generation, since it improves separation at source and reduces the amount of waste produced.

To facilitate the implementation of the incentive rates within the municipalities, a solution is necessary to identify the users of the waste containers as well as the deposited content. As it will be seen, this is achieved, generally, through the help of an on-board computer in the collector and a RFID identification system, which allows to acquire all the data of the collection.

However, although these systems work properly in the door-to-door collection systems, in the case of collection through voluntary contribution areas, the difficulty of identifying the user together with the deposited waste increases. At present, the solutions employed involve the use of smart containers, which require municipalities to make a significant investment in new containers (since there is not a solution to take advantage of the existing containerization), as well as the payment of monthly fees for the costs of data transmission and management of

[3] Ramón Pérez Hernández, Desarrollo de prototipo de sensor IoT usando la red SigFox. Departamento de Ingeniería Telemática Escuela Técnica Superior de Ingeniería, Universidad de Sevilla, 2015.

[4] Aditya Kaushal Ranjan, Muzzammil Hussain, Terminal Authentication in M2M Communications in the Context of Internet of Things, Procedia Computer Science, Volume 89, 2016, Pages 34-42, ISSN 1877-0509, http://dx.doi.org/10.1016/j.procs.2016.06.006

the digital platform.

Objective

The objective in the workpackage 2 is to develop a Smart container that allows to identify customers or citizens and garbage bag, equipped with different technologies: a user identification system, identifiable labels for deposited garbage bags, data transmission by LoRa/SigFox, and anti-fraud measures.

The competitive advantage that is searched in the solution goes through, on the one hand, to achieve the design of a system that allows adapting the user identification system and content of the waste bag to the different models of containers used in the European municipalities. And on the other hand, to find a simple solution with sustainable operating and maintenance costs. Therefore, it is not a question of building a new container, but of designing a versatile kit for each type of container, which allows to take advantage of the existing container networks.

This deliverable will focus on the system design and the preliminary specifications. More concretely, the objective is to develop:

- A first draft of the container design and architecture
- A list of materials and components

Scope

The scope of this document include all the elements concerning the collection system. To achieve the objective of obtaining a draft of a smart container, were studied:

- The regulations
- Opening systems and user identification
- Data transmission
- Reading system of the trucks
- Other systems in place in Europe
- The description of the collection system in place in the pilot cities
- The user requirements

So, the following elements are out of our scope, even if they are linked to the work package 2:

- The anti-fraud systems will be developed in the next deliverable
- The route optimisation module (ITENE, WP3)

Methodology

To complete successfully our part in the project, we used a structured project management method call PRINCE 2 (PRojects IN Controlled Environments). This method aims to divide projects into manageable and controllable stages. We developed the initiation phase of the project, consisting in identifying the project goals, scope, project organisation, business case, constraints, stakeholders, risks, and communication plan. All this information has been gathered in a document called "project initiation documentation". Furthermore, we got in contact with the partners involved in the work package 2 and organized several meetings to work on the common objectives together.

To complete this first deliverable, we developed a state of the art focused on the elements needed to develop the system, by researching in existing literature. Then, we sent questionnaire to the cities where the pilot projects are going to be implemented. Thanks to those questionnaires, we collected all the information needed to get an overall view of the actual collection systems and features, as well as the pilot implementation areas. At the end, the information collected by the research and questionnaires lead to a preliminary design of the PlastiCircle system.

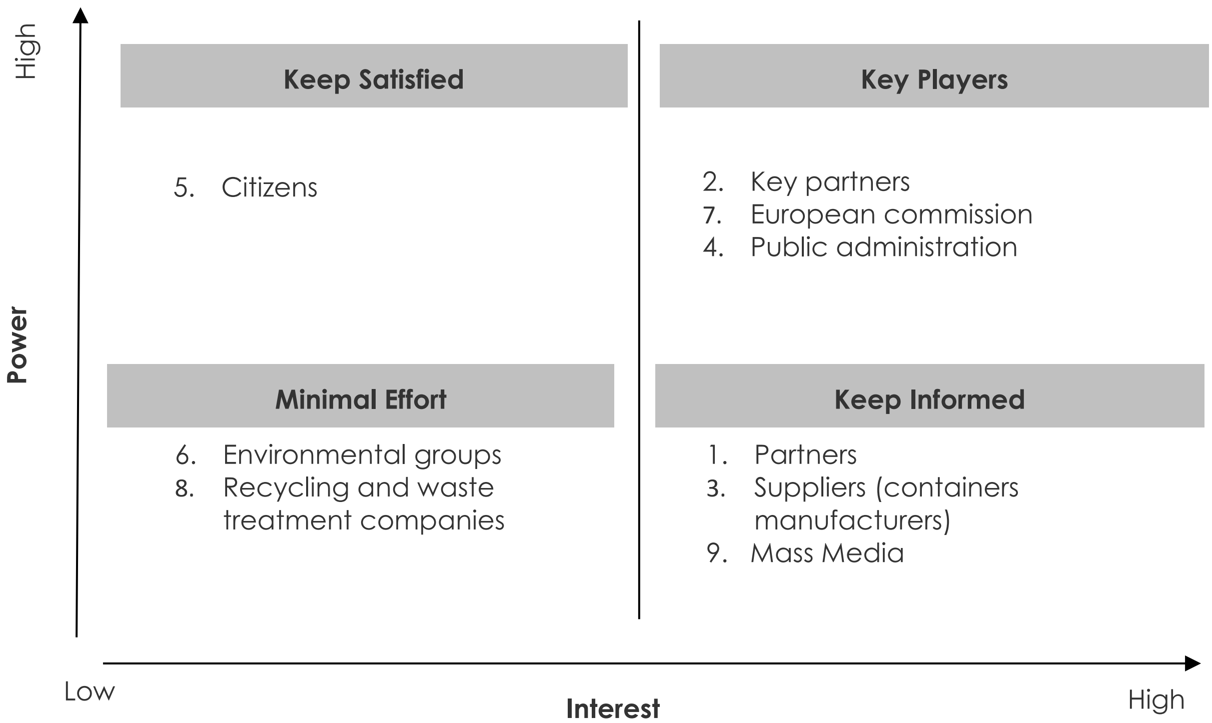
State of the art

1.1 Stakeholders

The following stakeholders of the working package 2 have been identified:

- The key partners
- The other partners
- Suppliers (containers manufacturers) plasticomnium
- Public administration
- Citizens
- Environmental groups
- European commission
- Recycling and waste treatment companies
- Mass media

We have classified them according to the following "Stakeholder Map" or "Power/interest Matrix"[5].



[5] G Johnson & K Scholes, Exploring Corporate Strategy, 5th Edition, Prentice Hall 1999

The stakeholders are classified according to their interest and power within the project. It results in 4 categories:

- The stakeholders to keep satisfied
- The keyplayers
- The stakeholders to keep informed
- The stakeholders that only require the minimal effort

It results that our key players are our **key partners** (ITENE and the cities), and also the **European Commission** and the **Public administration**. It's important to notice that the citizen have to keep satisfied too, because they have a lot of power in the project. They are the key of the project success.

1.2 Regulations

For the implementation of the prototypes, the following mandatory and voluntary legal requirements have been identified to be taken into account in the present design of the smart container. The possible application of new legal requirements will be reviewed throughout the subsequent phases of the design.

1.2.1 Compulsory requirements.

- Standard UNE-EN 12574-1: 2007: Stationary waste containers - Part 1: Containers with a capacity up to 10000 liters with flat or dome lid(s), for trunnion, double trunnion or pocket lifting device.
- UNE-EN 12574-2:2007: Stationary waste containers - Part 2: Performance requirements and test methods.
- UNE-EN 12574-3:2017: Stationary waste containers - Part 3: Safety and health requirements.
- UNE-EN 1501-1:2012: Refuse collection vehicles - General requirements and safety requirements - Part 1: Rear loaded refuse collection vehicles.
- UNE 170001-1: Universal accessibility. Criteria to facilitate accessibility to the environment.

  Part 1: DALCO requirements: Set of requirements relating to the actions of ambulation, apprehension, localization and communication, which must be met to guarantee the universal accessibility of the environments, products or services and thereby facilitate universal accessibility to the built environment.
- UNE 170001-2: Universal accessibility. Criteria to facilitate accessibility to the environment. Part 2: Universal accessibility management system.

- The CE Marking.
- ISO/IEC 11784-11785, ISO 10536, ISO 18000: on privacy and data security.
- ISO 14223/1: radiofrequency identification, advanced transponders and radio interface.

1.2.2 Voluntary requirements

- PRINCE2 (Projects IN Controlled Environments)
- UNE-EN ISO 9001:2015: Quality management systems - Requirements (ISO 9001:2015)
- UNE-EN ISO 14001:2015: Environmental management systems - Requirements with guidance for use (ISO 14001:2015)

1.3 Opening systems and user identification

In general, systems with user identification makes the user aware of their own waste production and make them to involve more efficiently in the waste selection.

Radio Frequency Identification (RFID) chips is a preferential option in container identification due its protection against manipulation and extremely high identification rates under difficult conditions. Each chip contains a unique ID that it is associated with a specific data such as the user name, invoice address, etc...

Users can be identified also by a bar code or a QR code. In this case, a code reader device is necessary to identify the user. Other user identification could be possible through mobile applications.

The door-to-door systems have allowed to reduce the anonymity of the users. This have increased the levels of separation of the different fractions in terms of quantity but also in terms of quality reducing the levels of the improper fraction to values of the percentage of a digit.

The benefits of the individual identification of the waste has therefore been manifested. This has generated interest on the part of the administrations to replicate the system in areas of voluntary contribution. To meet this need, the private industry has developed ICTs solutions that can be found today in European municipalities. In the following, the opening/locking systems of the lid of the container that allow identification of the user are reviewed, however in section 1.7.8. (Innovative collection systems), the reader will be able to find additional information about user identification systems that do not incorporate closure systems.

In Spain, the ROS ROCA company provides its Optiacces control device, which allows the restricted use of a container only to authorized persons, through a magnetic card. With restricted access, this application aims to encourage a correct separation of waste by the user, by establishing a control over who uses the container, as well as if the user performs the selection of fraction in a timely manner. The data is transmitted daily to a central of management of the waste collection to determine if the neighbours that use those containers are doing a good selective collection. Also, the monitoring of the frequency of the use of the container contributes to optimize the collection routes.

Figure 1. Optiacces control device with restricted access and user identification

The Italian company of weighing systems, Baron, developed consignment control systems that are electro-mechanical locking devices with user identification. It allows to reuse existing containers as the system is adapted to the existing models. They are self-powered thanks to a photovoltaic power. The opening is made by inserting a RFID card into the slot or by flashing a RFID keyring dongle. The transmission of data is performed via GPRS.

Figure 2. Baron consignment control systems with user identification, self powered by photovoltaic cells.

HORUS-CALOTTA, another Italian company base in Brescia, developed another device for identifying the user with an automatic opening system. The data is transmitted via GPRS. It is adapted to existing container models.

Figure 3. HORUS-CALOTTA device with user identification and automatic opening system.

1.4 Sensors

There is a very wide range of suppliers and manufacturers of sensors for waste containers in the market. Sensors in containers can measure the fill-level of the container, the concentration of gases like methane or the humidity of the container.

1.4.1 Filling sensors

Currently, the MSW collection is based on predefined routes based on experience. This causes unnecessary costs and over use of the equipment. Occasionally, empty containers are collected, and other full containers are overlooked, producing extra costs for the waste collection and neighbourhood complaints. Because of this, a tool that allows to know in advance the filling level of the containers seems a priori advantageous. ICT offers an innovative way to address these issues by giving instant access to the information, in remote locations and at a relatively low cost[6].

A filling sensor is an autonomous electronic system, powered by batteries, installed in a collection container to know the filling percentage of the container.

[6] M.A. Hannan, Md. Abdulla Al Mamun, Aini Hussain, Hassan Basri, R.A. Begum, A review on technologies and their usage in solid waste monitoring and management systems: Issues and challenges, Waste Management, Volume 43, September 2015, Pages 509-523, ISSN 0956-053X

Figure 4. Position of the filling sensor in a container.

The choice of the type of sensor will depend first on the type of technology and connectivity that is needed. The device should have a long battery life and it should be manufactured with an adequate encapsulation to work in the conditions of use of the container. A filling sensor, apart from indicating the filling percentage, also offers the opportunity to know other variables:

Drop of the container and time of emptying: almost all the sensors today have an accelerometer, so it is possible to know at what time the container has been emptied by detecting the movement. It is also interesting if a container due to acts of vandalism or the wind is down, since this can avoid accidents on public roads.

Position: Some filling sensors have GPS. This allows, for example, to know if the container has been moved from its position, but it has the disadvantage of reducing the battery's life.

Fire and odor warning: Almost all models include a temperature sensor. So, it is possible to know if fire is occurring inside the container. In addition, in summer, depending on the temperature recorded, it could be convenient to empty organic containers that, without being full, are generating odors by degradation of organic matter.

U-Dump M2M is a wireless sensor that can be installed in waste containers to measure the filling percentage. The distance is calculated in the sensor from the echoes received by the ultrasonic transducer. The filling percentage is estimated in the platform based on the heights of the container configured during installation. The data is transmitted through the cellular network directly to the platform. The algorithm used to generate information prevents false filling and emptying alarms which could be produced due to the non-uniform distribution of waste inside the container. The U-Dump M2M sensor includes an embedded SIM on chip card which operates worldwide and a SIM holder for use in case of preferring to transmit through a specific mobile network. The sensor is secured using rivets on four points of its circumference so that it is firmly attached to the structure of the container minimizing risk of vandalism. After installation the antenna rests on top of the container lid avoiding any alteration of the transmission in case the lid is metallic. The sensor works in any type of container, irrespective of its manufacturing material and for any type of fraction of waste or liquid. The maximum height of the container for complete reading of the fill level is 4 meters. U-Dump M2M detects the presence of fire inside the container and instantly sends an alert to the platform so that it notifies the indicated person or entity of the incident. U-Dump is designed to work for 10 years with the default measurement and transmission parameters and under normal environmental and coverage conditions.

Figure 5. U-Dump sensor to measure the filling percentage of waste containers.

Smartbin™ supplies a fill-level sensor for waste containers. The sensor provides ultrasonic fill-level, geo-location and temperature. The device is completely wireless with 3 plus years battery life. The device can be mounted in any container and it enables transmission data via LoRa, Sigfox & cellular networks.

Figure 6. Smartbin™ fill-level sensor for waste containers.

The MOBA FLS 100 is a wireless control device of the container fill level. It uses ultrasonic measurement technologies. The data is automatically transmitted to the web server using standard mobile telephony (GSM) networks. Users can check, in real time, the status of their containers at any time. Up to 10 years of life is achieved without replacing the batteries with the standard configuration. The use of the FLS 100 in conjunction with the MAWIS U2.0 route optimization management software allows increasing the efficiency of the collection. The device incorporates also a temperature sensor that allows alarms, in real time, in the event of a fire inside a container.

Figure 7. MOBA FLS 100 control device to measure the container fill level.

The Horus® system provides a volumetric sensor to monitor the filling of the container. It includes a temperature sensor to generate fire alarm.

Figure 8. Horus® device with volumetric sensor.

1.4.2 Sensors with camera

In 2012, a start-up called Compology[7] created WasteOS, which is composed of a wireless sensor and a routing software. Their sensor uses a different technology from their competitors: a camera. Images snapped by the sensors are transmitted over the cell network and processed by cloud-based algorithms to detect the fill level of the waste container. The most interesting and innovative feature reflected with the addition of the camera, is the capability of determining the contents of a waste container and its potential value, previously to the collection process. In addition to the quantity of waste allocated in a container, using the camera of the device it is possible to determine which are the contents of the bin. Combining this information with auxiliary sensors that detect other properties such as pH, density or temperature, they can generate specific information about the value of the waste before collecting it, thus allowing an efficient planning of the collection routes.

[7] Compology, waste collection sensors: https://www.postscapes.com/waste-collection-sensors-compology/

Figure 9. Compology sensor built in camera to determine the fill level and contents

1.4.3 Solid state methane sensor

A metal oxide semiconductor (e.g., SnO_2, ZnO_2,) is used to fabricate chemical sensors for several gases, in particular methane. The potential of this technique is based on the low conductivity of the material in clean air, which increases with the methane gas concentration in the air. The methane sensor indicatives of organic waste fermentation processes occurring within the container.

1.5 Data transmission

There are different technologies of data transmission depending on the bandwidth. The bandwidth here indicates the amount of data that can be transmitted in a fixed amount of time. Wireless mobile telecommunications technology as 3G or 4G allows a fast data rate transmission. While low bandwidth technologies as ZigBee or SigFox have lower data transmission rates but still useful in IoT as the data sent by sensors are normally small.

The data received is storage in databases on network servers. This storage data is processed by the software (or cloud platform) by means of calculus algorithms through the Big Data to provide predictive models to the user and provide geospatial information.

It is necessary to study which data transmission technologies are the most adequate to design a network architecture according to the arrangement of the containers and the physical environment where they are located. A well-designed network architecture should have low cost and low power consumption. Factors such as range, transfer speed, safety, power and autonomy determine which is the best wireless network to be used. It is generally necessary to send few data with the minimum possible energy effort. Then while the telecommunication operators focus their efforts on building increasingly advanced networks to provide greater bandwidth, the applications for the IoT are far from this concept. The reason is simple: the devices are in sleep mode most of the time and when they are not, they transmit small size data. A large bandwidth increases the energy consumption and moves away from the purpose, since we look for low consumption and cost savings[8].

1.5.1 ZigBee technology

ZigBee is a wireless communications standard based on the IEEE 802.15.4 wireless personal area network (WPAN). It aims at applications that require secure communication, with low rate of data sending and maximizing the useful life of the batteries. So it meets the requirements for IoT.

ZigBee devices are often used in mesh form to transmit data over long distances. Each node sends the data to intermediate devices to reach far distances, since the transmission distance for a ZigBee node in urban areas is about 100 meters. A ZigBee unit can be found in sleep mode most of the time, increasing the half-life of its batteries.

The ZigBee network applied to the collection of waste is composed by repeaters and hubs that store the data from several containers to be sent after by GPRS to the remote server.

Figure 10. Embedded Zigbee and Thread-ready RF module

1.5.2 GPRS technology

Most of the current communications between smart containers and the remote server are done through GPRS cellular connectivity. This was the first technology that was available when the first deployments of sensor networks were created.

Any IoT application that needs to operate in large areas (wide coverage) can benefit from the advantages of GSM / 3G / 4G mobile communication. The range

[8] Ramón Pérez Hernández, Desarrollo de prototipo de sensor IoT usando la red SigFox. Departamento de Ingeniería Telemática Escuela Técnica Superior de Ingeniería, Universidad de Sevilla, 2015.

is up to 35 km for GSM and up to 200 km for HSPA. On the other hand, the energy consumption and the economic cost of the connection are quite high. These networks are therefore considerably less suited to situations in which the unit transmits few data or operates in battery mode (without a power supply).

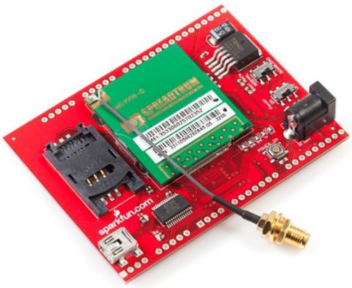


Figure 11. GSM/GPRS Module - SM5100B

1.5.3 Lora protocol

LoRaWAN is a specification of a LPWAN (Low Power Wide Area Network) network proposed by the LoRa Alliance and designed to communicate devices of low cost and low consumption powered by batteries. The connected objects compatible with LoRa communicate with a hub and it connects to the base station through the low-speed, long-range LoRa network. It can perform broad networks with millions and millions of devices. Its data transfer speeds range from 0.3 kbps to 50 kbps.

LoRa is especially suitable in situations where long-range connectivity and long battery life are needed, where using other connectivity standards means too much power or lack of range. In addition, any company or agency can buy a LoRa base station and build its own network, so it can be exploited as a private network. LoRa allows only the transmission of 1000 bytes per day. However, it is sufficient for the monitoring of waste containers. One of the advantages of LoRa is that it is an Open Source technology.

Figure 12. Lora technology module.

1.5.4 Sigfox low consumption networks

Sigfox responds to the needs of many M2M applications that run on a small battery and only require lower levels of data transfer, where WiFi is too short and mobile communication is very expensive and consumes too much power. Sigfox allows remote devices to connect using ultra-narrow band technology (UNB). Sigfox-based sensors can not perform large amounts of data, approximately 12 bytes per message, and not more than day149 messages per day per device.

Sigfox has a low power consumption because it is only used when the object needs to transmit payload. It uses between 45 and 55 mA in the transmission and values that go down to the µA in sleep mode.

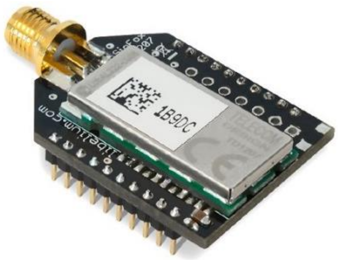


Figure 13. Sigfox module.

1.5.5 IoT cloud platform

An IoT cloud platform is the support software that receives and allows to manage and visualize the information sent by the sensors. One of the main features of these platforms is that they are cloud-based and have the ability to be managed, maintained, and accessible from anywhere. The platform projects a layer of sensors deployed throughout the city to collect and transmit information from them. There is a wide range of commercial platforms like Enevo, SmartBin or MOBA.

1.6 Reading system (trucks)

To offer incentive formulas, it is necessary to be able to trace the origin of household waste. This is allowed by the radio frequency identification (RFID) technology. By using RFID technology, waste can be identified and traced through the entire waste chain.

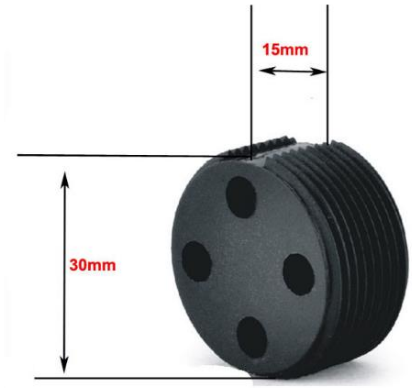


Figure 14. Passive label of the trunk Em4305, reject of IDENTIFICATION RF of 125kHz waste management

The use of the RFID technology in waste containers started 10 years ago with the purpose to optimize the waste management through the Pay as you throw (PAYT) system. In this system, the companies pay the taxes of the waste collection in function of the waste they produce and their recycling rate.

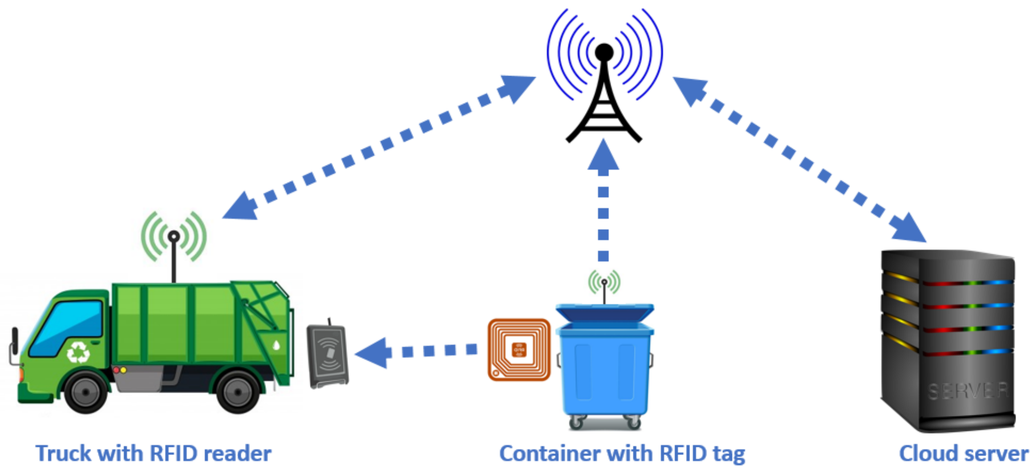


Figure 15. RFID System

The waste containers in this case are equipped with RFID tags. These tags have a unique ID, which is associated either with a single container that serves a community of citizens or a single user in the case of personalized or door-to-door services. The collection trucks incorporate RFID readers to register the volume of the collected waste and the sorting quality for each container. The readers record the exact time and location every time a waste container is emptied. This introduces a new degree of monitoring and control of the waste disposal process. RFID tags simplify service billing and support implementation of PAYT systems and incentive formulas. RFID used with GPS provides also real-time visibility to the waste management activities. The real-time aspect allows municipalities to monitor performance of contractors.

RFID technology uses three frequency ranges: low frequency (125 or 134.2 KHz), high frequency (13.56 MHz) and ultra-high frequency (UHF, 868 MHz).

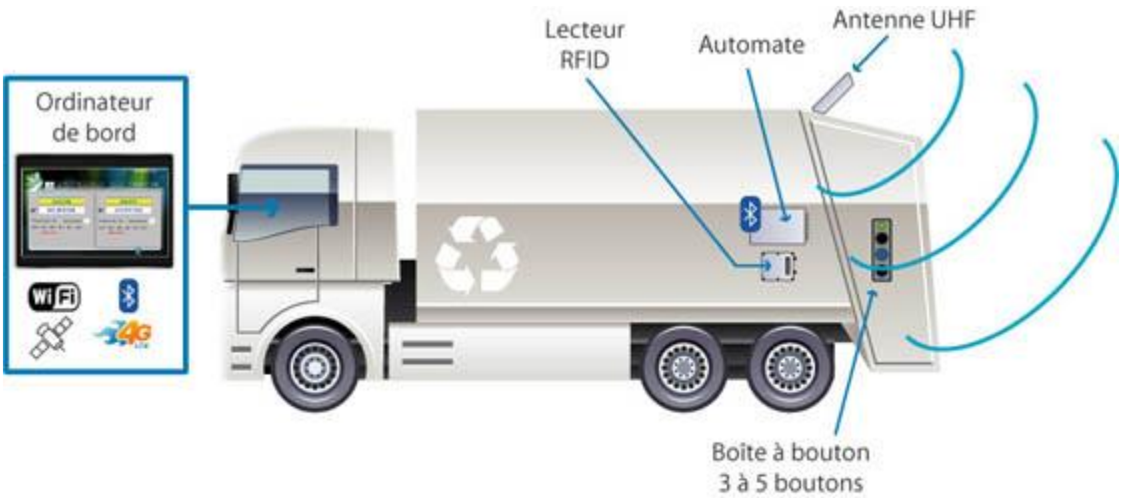


Figure 16. Fuente AGID designs and integrates identification and traceability systems

Low frequency solution 125kHz and 134.2kHz

In low frequency, the identification is done directly under the rim of the tray, we set up a perfectly adapted reading system.

Ultra high frequency solution

In ultra high frequency, RFID tags can be located under the rim of the tray or on the front of the latter. In order to guarantee an optimal reading, a suitable UHF antenna makes it possible to read each chip efficiently.

Side collection solution

In lateral collection, the mechanical and congestion constraints are strong. The use of the UHF is necessary in order to be able to read the dumpsters during the lifting.

To date, only two frequencies have been standardized at European level since August 2006: low and high frequencies. UHF has not been standardized yet due to the risk of reading error due to the distance and metal disturbances. The low frequency of 125 kHz, mostly used, is the standard reference. The reading distance for this frequency is up to 4 cm maximum. The high frequency allows reading up to ten cm. In this case the chip is similar, but the reading antenna is different. The UHF can reach up to several meters.

There are several possible options for the placement of the RFID tag: placement of the UHF RFID tag directly in the waste container (resistant and durable tag) or directly on the plastic bag (disposable tag). RFID tags can face harsh environments and rough handling which makes this technology very interesting to be used in the waste collection process.

RFID is enabling municipalities to identify individual containers and can create incentive-based recycling programs that accurately reward customers for the amount they recycle, while minimizing the overall amount of trash. RFID can assure that individual bins have been collected, providing verification of service. In addition this information can be used to optimize truck usage and routes.

1.7 Collection systems in Europe

1.7.1 Door-to-door (DtD) or custom collection system

The model of door-to-door selective collection consists to leave the waste in front of the residences or commercial buildings, in days and hours determined for each fraction. The trash cans, once emptied, are re-introduced into the buildings and do not remain on the public road. This model has an indirect benefit in the public space: the removal of the containers in the public road (except for some fraction) and the substantial improvement of mobility and urban aesthetics. This system has a very positive impact on the quality of the recycling, avoiding that many waste goes to the landfill and bets for the environmental sustainability.

The DtD collection allows to obtain a good quality waste segregation. This is possible because, especially in small municipalities, the waste not delivered correctly is not collected by the management company.

In big cities, this system is being implemented in areas of difficult access for the collection trucks (historical centers) or low population density, but it is a model used generally for small populations. The system consists of the use by each family of a trash can. At an established time, these trash cans are left on the street until the pick-up service reach. The DtD systems can also contemplate areas of contribution, in this case called "emergency areas" for the selective collection of the rest of fractions (paper / cardboard, glass, packaging or organic).

Among the disadvantages of a DtD system, it should be noted: a greater effort for the citizen and the proliferation of bags or trash cans in historic centers (usually tourist areas). From the point of view of the staff, DtD requires more people and mechanical resources, which increases the cost of the service.

1.7.2 Collection through areas of contribution or sidewalk

In this system, the deposit points are no longer located door to door, but every 50-250 meters. The distance to be travelled by the citizens is not very high and the acceptance is good. It is applied in cities with high population density. Large containers of volume between 0.8 and 3.2 m3 are located in these points.

According to the disposition of the containers, the collection system is denominated in sidewalk or in area of contribution:

On the sidewalk: containers for selective collection are located on the street, very close to the user, to facilitate the maximum citizen collaboration. A distance of less than fifty meters is a good indicator of this level of collection.

In areas of contribution: the containers are located in a relatively distant area (between 80 and 250 meters radius), while the remaining fraction is located about

50 meters.

Both the collection by areas of contribution or sidewalk is more agile and faster than in the DtD and the costs are significantly reduced. The main problem is the number of different containers that must be located at the collection points.

At the same time, these systems can be classified by the collection procedure, mechanical or pneumatic, that is used. Thus, at present the most used systems are:

- collection by rear loading
- collection by lateral load
- collection by bilateral load
- collection by lateral load
- collection by underground containers (in any of the above variants)
- pneumatic collection

Among the problems of this collection system, it is the occupation of the public space, the possible appearance of spots of dirtiness and stains in the surroundings of the containers as well as, discrete rates of recovery and high quantity of improper, due to the fact that the participation of citizens in the system is voluntary.

In cities with a high population density, these collection systems predominate, coexisting in some cases with personalized collections or DtD generally in commercial areas.

1.7.3 Collection by rear load

Traditionally, the collection by rear loading has been the system more extended in Europe. The population deposits the separated waste in the containers located in the street, which has a capacity between 90 and 1100 liters. Then the rear load collector equipped with a compactor box collects the waste. The employers bring the containers to the back of the collector and the collector automatically empty the container. After, the compactor minimizes the volume of the waste.

Figure 17. Waste collection truck by rear load.

For narrow streets or those that present great complication for access, small collector vehicles with volumes of 3 to 7 m3 are used.

1.7.4 Collection by lateral load

This collection method has grown in popularity in the last 20 years. A vehicle provided only by a driver uses a right lateral mechanical arm to perform the process of emptying the containers. The mechanic arm loads and unloads the container from its location. This vehicle can only collect on one side, so it is necessary that there are not vehicles or other obstacles that avoids the emptying work throughout the container area.

In cases of overflow and / or difficult of access for the truck, it is necessary to have a vehicle called "satellite" that collects the bags outside the container, or to move the container to a place with better access for the truck to be returned to its site once has been emptied.

The capacity of the containers usually used in lateral loading is 1700, 2200 and 3200 liters.

Figure 18. Waste collection truck by lateral load.

1.7.5 Collection by underground disposal containers

The system of collection by underground containers consists of the use of opening systems and buried containers. To empty these containers the platform must be raised by remote control lifting the container for its correct emptying. There is an opening system for each of the waste fractions.

Figure 19. Underground disposal containers

This system allows the collection by rear, side or crane loading trucks. The use of this type of system is purely aesthetic and requires high initial investment and maintenance costs of the electromechanical systems.

1.7.6 Pneumatic collection

The system of pneumatic waste collection consists of having a series of entry points connected, through subterranean conductors, to a point of aspiration. Entry points can be found inside homes, in community areas inside buildings or in public outdoor areas. The collection cycle starts when the waste is deposited in the opening systems. Then, by gravity, the waste falls to the installed valves at lower levels and it is accumulated there temporarily.

Figure 20. Entry points for pneumatic collection.

The pneumatic systems are divided according to the aspiration process in static or mobile.

Static system: The pneumatic collection system uses air to transport the waste through an underground network of pipes to a collection center, where they are compacted in closed containers. This air flow is generated by the extractor tubes, which create a negative pressure in the wall. When air enters by the collection points at atmospheric pressure, it drags the waste to the collection center.

Mobile system: This system has vertical downpipes connected to containers. The containers are connected by pipes between them by groups and each of them has a suction point, where a vehicle aspire periodically the waste.

The main advantage of the pneumatic collection is that it minimizes the inconvenience due to the collection of waste, such as vehicle traffic, CO2 emissions and noise. In addition, it prevents the introduction of certain types of improper waste due to the small size of the opening systems. On the contrary, the use of these systems needs a high investment. Also, the implantation in already consolidated urban areas is complicated and the energy cost is very high.

The collection of the pneumatic system can be by level or by schedule.

- By level: the waste is collected at any time once they signal that they are full (or at the predetermined level) is emitted. This system has the advantage that energy consumption is reduced.
- By schedule: all the waste containers are emptied and transported, sequentially, at specific times programmed by neighbourhoods or itineraries. The installation is out of use the rest of the time. This requires a citizen information campaign of use. In this system, it is easy to find waste bags outside the entry points due that the limiting times of deposition.

1.7.7 Collection through the bilateral system "Easy"

The so-called "easy" system has many similarities with the lateral loading system, with the difference that the emptying of the containers is carried out by means of top loading and it is also indifferent that the containers are to the right or to the left of the vehicle. It is a fully automated system, in which the driver of the truck, without the help of any other employer, controls all movements of the vehicle during the loading and unloading process. In this system, the robotic crane empties the container and leaves the container in the exact same place where it was collected. The disadvantage of this system is the high cost. On one hand, the price of containers is double that of a side-loading container and five times more than a rear-loading container. On the other hand, due to the use of the power take off for the unloading, the energy cost in the collection stage is higher than in other options.

Figure 21. Easy collector truck

1.7.8 Innovative collection systems

User identification

The identification of the user is easier in the towns where a personalized or door to Door (DtD) collection system is implemented. In this case, identification systems in bags or chips in the waste bins, are used. This is the case of the municipality of Totana or some of the German municipalities of Baden-Württemberg. The operation is simple in some cases, waste collection vehicles have readers (scanners) that read the identification number of the container through the chip (RFID) every time the container is emptied. In this way, the collector, once it arrives at the base (or in real time), transmits the data to the cloud. Then, it is registered when waste containers have been emptied and by which vehicle, and the weight of the collected waste. Another method consists in the use of bar codes, which are either pasted to the bag or the container. The bar codes are read manually by means of a hand-held scanner. An example of this system is used in the German city of Mülheim.

Figure 22. User identification system "Ident" for waste containers in the German city of Mülheim

In municipalities with a collection system of community containers, the user identification requires a computer system and a card reader in the container. The user is identified, and then the amount of waste is measured by volumetry and registered by the system. In this case, the municipalities need heavy investments to achieve the identification of the user, as the renewal of the entire container network is needed (it is not possible to implement a kit in each container). Due to that, this system involves monthly service fees for the users.

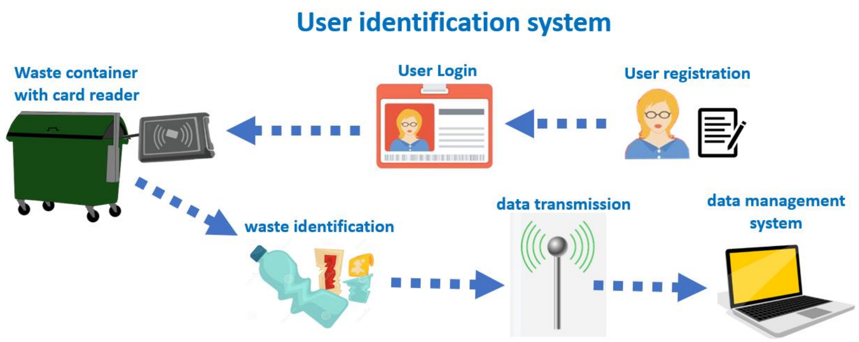


Figure 23 System of user identification

Figure 24. Containers with user identification, in the Spanish village of Alcalá de Xivert.

Given this context, this project addresses the challenge of achieving the identification of a user, by designing a container without heavy investments by the municipalities. It aims to take advantage of the existing containerization system and the use of IoT technologies by through a sampling procedure and subsequent user's reward, to increase the quality and quantity of the plastic waste collected.

Other innovative systems

Most of the existing smart containers are capable of determining the fill level of a container and report it to a remote server, in order to use this information to optimize the collection routes. Among other capabilities, there are systems that know the person who recycles, machines that give money in exchange for recycling, systems that notify when they are full and compact the garbage, containers adapted to people with disabilities or containers with screens that give information. The most interesting cases are described below.

One of the pioneer companies in the ambit of the monitoring of the waste container fill level is sigrenEa[9]. This company (at first called aEnergis) launched an innovative system that can detect the fill level of trash containers, and send the data periodically to a remote server via the GPRS network. The data is used to optimize the collection routes and manage the resources efficiently. It uses an ultrasonic sensor to determine the fill level of waste containers. It is equipped with a Dual-Band GPRS module for long range communications, and also with a WM-BUS (Wireless Meter-BUS) module, which makes possible short-range communication with specific hardware provided by the company. The system can be complemented with a Global Positioning System (GPS) receiver, to maintain a precise location of the container. The system disposes of small batteries which can last from 5 to 12 years without replacement. The built-in batteries can be replaced easily if it is necessary.

The city of Groningen (Holland) has implemented containers that are opened only when the user is identified, thanks to an RFID reader on the lid.

In Spain, the town of Lazkao has installed 5 pilot containers of organic waste for composting. Volunteers receive a personalized card to deposit their waste. The objective is to create a system that rewards those who recycle and raise taxes to those who do not.

In Vitoria (Spain) containers of organic waste, paper and light packing have been installed to inform their location, the weight of the waste and when it was the last time it was emptied. In addition, the administration is able to optimize cleaning routes and save time and resources.

Abu Dabi have deployed solar-powered bins. The bins are equipped with intelligent sensors that communicate with the command centre when it is full. So collection teams can come and empty it, while solar panels power a compactor, enabling the bins to collect five times more rubbish. Also, it has been deployed the introduction of Recycling Vending Machines (RVMs), which accepts plastic bottles and aluminum cans and separate them inside the machine before compacting the material separately.

Figure 25. Solar-powered bins in Abu Dabi.

For the 2012 London Olympics, bombproof bins where introduced with LCD screens capable of giving news, information about traffic and transmit updates during emergencies.

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[9] SigrenEa, connectivity for smart recycling: http://sigrenea.com/es/soluciones-materiales/

Figure 26. Waste bins with LCD screens in London.

Reverse vending machines that accepts used (empty) beverage containers and returns money to the user are common in some cities. In some places, bottlers paid funds into a centralized pool to be disbursed to people who recycled the bottles. In Germany and Holland, the recyclable containers carry information so that the consumer can return them in the specific machine and these validate them. Afterwards, the machine reimburses the consumer for the deposit that was paid as part of the package. Any excess funds is used for general environmental cleanup[10]. The user places the empty bottle or can into the receiving aperture; the horizontal in-feed system allows the user to insert them one at a time. (An alternative system, found in many older machines, is one in which the user opens a door by hand and places the empty container in a pan. When the door is released and closed, the process continues.) The bottle or can is then automatically rotated; the bottle or can is then scanned by an omnidirectional scanner, which scans the beverage container.

Once a bottle or can is scanned, identified (matched to database) and determined to be a participating container, it is processed and typically crushed to reduce its size, to avoid spillages of liquid and to increase storage capacity. Refillable containers are collected and sorted by hand to be brought back to the bottling company. The machines can use material recognition as well as a bar code scanner when needed[11].

As example, vending machines in subway stations throughout the city of Beijing were installed in order to encourage people to recycle more. When a passerby inserts an empty plastic bottle, the machine’s sensor scans it to assess the value of the plastic – anywhere from 5 to 15 cents – and spits out a public transportation credit or extra mobile phone minutes. The reward is commensurate with the quality and number of bottles being fed into the machine.

[10] http://www.bottlebill.org/

[11] http://www.reversevending.co.uk/

Figure 27. Recycling vending machine in Beijing subway stations with system of reward.

Bigbelly provides a smart bin which compacts the rubbish by means of solar-powered energy[12]. Although solar power is still an important feature, the company has created self-powered stations for use where sun may not be available. The compaction mechanism exerts 5.3kN of force, increasing the bin's effective capacity by five. The compaction mechanism is chain-driven, using no hydraulic fluids. Maintenance consists of lubricating the front door lock annually. The mechanism runs on a standard 12 volt battery, which is kept charged by the solar panel. The battery reserve lasts for approximately three weeks. Wireless technology-enabled units report their status into the dashboard that gives waste management and administration insights for monitoring and route optimization.

Another container that compacts the rubbish by solar power is supplied by the Spanish company Formato Verde[13]. It operates completely autonomously without the need of electrical power thanks to the installation of a battery system and solar panels on the top of the equipment. The system is intended for the use by general public. It aims to reduce the cost of waste collections due to its big capacity of 40 m^3. The container can be adapted to every type of waste (garbage, packages or paper) by installing specific apertures on the disposal drum.

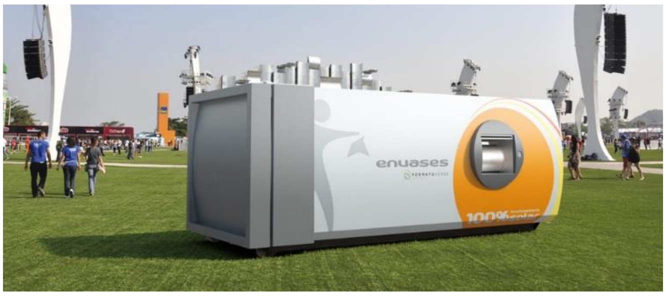

Figure 28. Solar-powered container developed by Formato Verde.

Sensors to detect vandalism acts, such as container displacements or fire has been deployed on prototypes[14]. The work involves research about distance

[12] http://bigbelly.com/
[13] http://www.formatoverde.com

[14] Cristian Moreno Ruiz, Design of a M2M waste container system for a Smart City: http://upcommons.upc.edu/handle/2117/100135

measurement algorithms, and hardware components needed for the system measurements, as well as featuring fill level, acceleration and flame presence measurements.

2. Description of pilot cities actual collection systems

2.1 Valencia

The waste fraction of the domestic packaging is the fraction that most concerns the Valencian administration, so there is a wide debate on the best management for this waste.

The selective collection in the Spanish State and therefore in the city of Valencia, is based on the fact that the packers are charged by a part of the economic cost of the management of their potential waste. To do so, each package that is placed on the market pays an amount to contribute to the cost of collecting, transporting, recycling and the cost of information campaigns. To identify the containers that have the right to be recycled, the called "green dot" is used, a symbol with two intertwined arrows.

2.1.1 Collection system

The collection system for the fraction of light or plastic packaging is by lateral load with the collection model of "areas of voluntary contribution". The containers of this fraction coexist next to containers of other fractions as paper and cardboard as well as glass and organic fraction in some cases.

Figure 29. Containers of Valencia

2.1.2 Service features

Frequency and number of collected containers

The area of Valencia where the pilot will take place consists of 4 routes with an average of 90 containers, each of them with a capacity of 3200 litters. The containers are emptied with the frequency of two days a week.

Mechanical resources

The collectors employed in the waste collection service operate by lateral loading with a capacity in volume of 20 m^3. The entire collection process is made by the right side of the collector.

User identification system

Currently, user identification systems are not used in packaging containers, as well as other types of smart mechanisms such as volumetric sensors.

Deployment of incentive policies

There are currently no incentive policies to reward the proper segregation of waste. The action undertaken by the administration consists of the implementation of awareness campaigns focused on reducing the amount of improprieties that are collected in the fractions. This objective is prioritized over increasing the amount of collected material.

Awareness policies

According to the last report on environmental awareness in Spain of EAE business School, there has been a positive evolution in the Spanish society and, of course, in the Valencia Region, which is the fourth region in terms of waste generation. This positive evolution is based in following facts:

The rate of domestic waste recycling has improved from 4.8% to 74,8% in 2015.

The use of urban transport, sorting of domestic waste and energy home costs reductions are issues considered as already assumed by Spanish population. The sorting rates are, however, still to be improved in case of electric and electronic devices, plastic, batteries and oils. The main reasons for not sorting are: lack of space at home, lack of containers and distance from home to the containers.

Population begins taking into account environmental issues in consumption decisions such as cars and long travels

Population is highly concern about air and water population, whereas it is not aware of the impact of our habits in the extinction of wild habitats and animal species.

2.1.3 Proposed area for the implementation of the pilot.

The chosen pilot area is Sant Marcel.li -, which belong to the Jesús District of Valencia city:

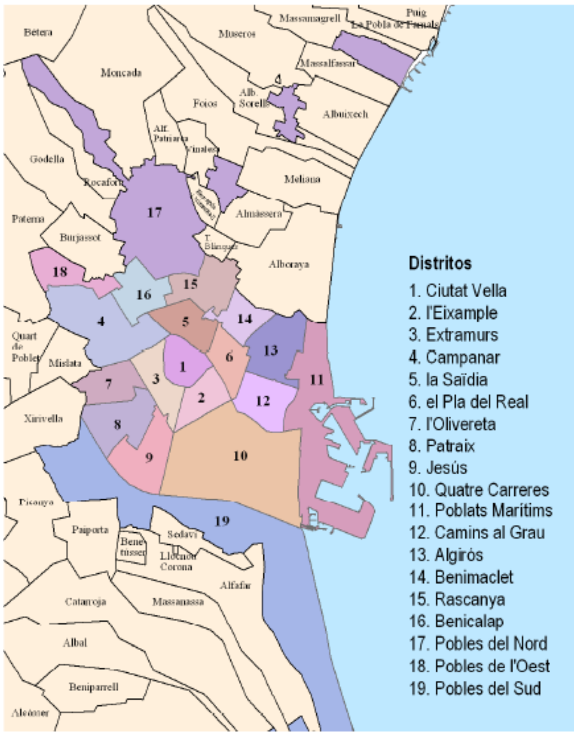

Figure 30. Districts of Valencia

Sant Marcel.lí was built in 1954 by the Archbisop Marcelino Olaechea to host the increasing homeless originated both for the post civil war years and increasing immigration of people from the country side seeking for jobs. Being the lack of housing the major problem, the urban planning gave priority to their construction and not the infrastructures provision, which came later.

Presently, this are the main figures:

- Population: 10 000 inhabitants
- Population density: 305 inhab/km2
- Area: 0.33km2

About numbers of containers, these are the figures compared to the whole city:

	Papeleras	Papeleras/ 1.000 hab	Contenedores Basura (RSU)	Cont. Basura (RSU)/ 1.000 hab	Vidrio	Cartón	Envases ligeros	Aceite vegetal	Contenedores de pilas
València/Valencia	15.068	19,1	9.647	12,2	2.047	1.886	1.795	104	143
9. Jesús	700	13,4	447	8,6	115	109	110	6	7

We can appreciate that the values are below the average rates of the city in terms of 100 hab, which confirms the lack of waste collection infrastructures.

2.2 Utrecht

Utrecht is a city in the central Netherlands with a population of 345,080 in 2017 with a population density of 3,658/km^2. Utrecht host the Utrecht University, the largest university in the Netherlands, as well as several other institutions of higher education. Due to its central position within the country, it is an important transport hub for both rail and road transport.

The city of Utrecht is among the best waste recyclers in the main cities of the Netherlands. Residents divide their waste into five types of waste:

- Paper
- Glass
- Organic waste (GFT)
- Plastic / cans / packing (PBP)
- Residual waste or rest

Figure 31. Utrecht underground container

2.2.1 Collection system

The collection system of plastic waste in the city of Utrecht can be distinguished between areas of highest population density and residential areas with low population density.

In areas of high population density, the collection of plastic is done through areas of voluntary contribution using the hook-lift system or crane. The containers are underground, and the capacities vary from 3 to 5 m^3.

In residential areas with low population density, the collection system is through personalized collection or door to door system. The lifting system in this case, is by rear loading. The containers used are cubes of 140 to 240 liters capacity.

2.2.2 Service features

Frequency and number of collected containers.

As discussed above, the service is divided into collection by hook-lift or crane and rear loading. In the case of residential areas with low population density, the

Figure 32. Transparent bags used for door-to-door collection

collection system is divided into 15 routes with a frequency of 3 days per week. In the case of underground containers in areas of high population density, the containers are emptied when the filling sensor indicates that they are full. Then, the routing is performed daily to empty the full containers.

Mechanical resources.

The collectors employed in the collection of plastic packing are driven by both diesel and natural gas.

User identification system.

As mentioned above, underground waste containers are used for communal waste. There are a few locations where households can deposit plastic, paper and glass by underground containers and three larger waste collection sites. Citizens must bring the waste to a collection site where the citizen is identified with a pass to open the underground container. Due to legislation, privacy data is not allowed to save. After identifying, the data is deleted. Only in some circumstances the use of this data is allowed.

Deployment of incentive policies.

The incentive policies are not planned to be performed in Utrecht. The feedback from Utrecht is that incentive policies would evolve high administrative costs and it would be almost impossible to reward each household on an individual basis. Then, the incentive policies are advised negatively in Utrecht. In the work session of the kick-off meeting in Valencia, Utrecht suggested alternatives about community reward instead of individual incentives.

Awareness policies

The waste processors in the Netherlands do not accept the collection of the light packaging fraction denominated "plastic, blik en pak" (PBP) in grey opaque bags. This is because it is not possible to see what the quality of the segregated material is. So, Utrecht is encouraging the use of transparent bags for door-to-door collection among its neighbours.

There is the paradox that before 2015 the company Plastic Heroe that managed the collection, among its campaigns distributed transparent bags for collection. But from this date, the municipalities are responsible for the collection and processing of plastic waste, and transparent bags have not been provided.

While in the global of the Netherlands, the amount of plastic collected has been increased in recent years, this fraction coexists with a high percentage of improper and contaminated plastics, so it has improved in quantity, but not in quality.

Another of the campaigns performed to improve the quantity and quality of the collected plastic waste has been carried out in 2016. In that year, the cans and packaging of fruit juices that until now were not collected in containers for plastic containers began to be collected. Then, an information campaign was carried out among the population to inform about the change.

Figure 33. Recycling information campaign

2.2.3 Proposed area for the implementation of the pilot.

4 possible zones have been addressed (see the attached PDF):

- PMD-INZ-314, 1925 households
- PMD-INZ-316, 1426 households
- PMD-INZ-326, 1904 households
- PMD-INZ-328, 1636 households

It is been suggested to use some of the 140 / 240 liter services routes.

2.3 Alba Iulia

2.3.1 Collection System

Polaris is the authorized company for individual houses' waste services for the entire city. For individual houses, yellow bag is used for paper, glass, plastic and cans. Polaris is sorting locally and sending sorted materials to specialized companies. Low quality waste and garbage is sent to dump. For associations of apartments in flat buildings, the yellow container is usually for recyclable materials, but waste quality is sometimes low, being mixed with garbage. More than that, there are poor persons gathering PET bottles left near containers for selling them to recycling companies for a very small fee. Local companies selling packed goods must have recycling contracts with Polaris or other authorized companies. These companies are sorting useful materials and have contracts for delivering them to processing units.

Starting next year, waste should be collected in five separate containers: garbage, paper, plastic, glass and cans. Complementarily, an integrated awareness raising campaign is foreseen.

2.3.2 Service features

Frequency and number of collected containers.

- Usually weekly for individual homes
- Daily for associations of apartments in flat buildings, according to estimated volumes and contracts
- The operator is obliged to empty and clean all containers and their area each time they collect the waste
- Operator can also answer to specific orders or emergency situations

Mechanical resources.

- 9 compactors (7 compactors of 16m3 and 2 compactors of 8m3)
- Brand: Iveco (Euro 3)
- Year: 2013
- Motor: diesel

User identification system.

Containers are provided by the waste management company and have their logo printed. For individual homes, all containers have also a printed unique serial number, which is mentioned on services contract. For blocks of apartments, large containers are provided to association and contracted as a collective service. For companies/ organizations, containers must also be labelled with company name. There is no automated identification of containers and no automated identification of users (apartments in flat buildings/ individual houses/ etc).

Deployment of incentive policies.

There are no incentives yet; Vouchers or discount to waste collection tariff is analysed.

Awareness policies

We don't have information about the awareness policies in Alba Iulia.

2.3.3 Proposed area for the implementation of the pilot.

Central city area, with associations of apartments in flat buildings and containers. Due to limited number of sensors, possible combination with a short street and individual homes is possible. Zone must be defined with other partners according to technical specifications for containers, available communications systems and minimum distances for an optimal route. The distance between the containers in the proposed area is variable – between 50m and 800m.

3. User requirements

3.1 Type of containers

The containers for the collection of light packaging can have different sizes and shapes as they are designed to be adapted to the chosen collection system. Also, the shape and colour of the containers installed on the public roads varies from one city to another since they are adapted to the physiognomy of the city. For this reason, we can find different models and colours in tows.

In order to improve the quality of the collected material, the containers have an adapted aperture, as well as a closing system that blocks the opening of the lid, preventing containers to be emptied by waste pickers.

According to the disposition of the containers, we can speak of two collection models:

- Selective collection in shared areas. In this method, large capacity containers, igloo type or lateral load, are used, which have entry points adapted in the upper part of the container to introduce the waste. The light packaging containers are placed together with the blue container and the green igloo for the glass.

  The material that is collected in these containers is usually of good quality, since its simplicity makes it difficult to produce errors when depositing the waste.

- Selective collection in sidewalk containers. In this case, the containers are smaller, rear loading type; although lateral loading containers are occasionally used. They are placed near the homes of the citizens.

This method is more convenient for citizens, due to its proximity, which ensures a high participation, although there is a certain risk of a higher rate of "improper" or materials that do not correspond to the container type.

Figure 34 Example of waste containers

3.2 Accessibility

The design of the smart container in this project requires a solution with the possibility of adapting the different types of light packaging containers that exist in the market. An integrated solution for the container would produce a greater cost for the administrations in the renovation of the container park. On the other hand, the development of a versatile equipment is a competitive advantage over other existing solutions, which will lead to the success of the solution as a business model.

This solution will be developed considering the accessibility for disabled and old persons by the new development elements created in the project, which will give the qualification of Smart to existing containers, elements such as the reader or user identifier and/or bag and the label dispenser. The accessibility conditions will be considered when installing them in the containers. It will be a compatible solution with an installation that favours accessibility to the container, such as height and location of the devices. The creation of a new container is not intended in this project, nevertheless the models of accessible containers that exist will have a full accessibility, that is, both in the mechanism for the introduction of plastic waste and in the user identification system.

3.3 Communication technology in city labs

Of the three technologies considered (3G, LoRa, Sigfox), not all are available in the pilot regions. For example, Sigfox technology is not available in the city of Alba Iulia. However, other technologies (LoRa and 3G) should be available in all 3 cities. The availability of LoRa in Alba Iulia still needs to be confirmed. The See table below.

	Valencia	Alba Iulia	Utrecht
3G	X	X	X
LoRa	X	(X)	X
Sigfox	X		X

Table 1 Availability of the considered communication technologies in the pilot cities

X: disponible

4. Preliminary design of the system

4.1 Design and architecture (preliminary version)

Figure 35 shows a preliminary architecture of the PLASTICIRCLE collection and transport system. It includes the different elements and parts (modules), and how information is transferred between them.

This scheme focus mainly on the Collection (WP2) and Transport (WP3) features of the PlastiCircle whole system.

D2.1. will focuses on the definition and characterization of the collection systems, including the main features to be included in the smart container.

The smart container has several modules:

- Identification module
- Label dispenser
- Filling level sensor.
- Vandalism protection features
- Communication module

The **identification module** will be able to read the information about the user participating in the project pilot. The first proposal for the identification module is the use of a NFC reader, to which the user will approximate a NFC card or mobile phone (which allows NFC technology).

Each user will need to previously register in the PlastiCircle database. For that purpose, different alternatives would be available:

1) An app will be developed, where the citizens could register and check/modify their information. Each user will get a user name and password to accede to the app. In this case, the mobile phone NFC technology will serve as 'smart card' for container using.

   Some parameters and performance indicators will be shown to the user via the app. Also the information about position of smart containers and filling levels could be included.

2) The project website will also include a link for the users' registration, which will automatically send the information to the project partner responsible of database management. This information will be stores in the data based and the user will receive an e-mail back with the information for the card collection.

3) As an additional option for less 'technological' users, each city will provide a physical registration point in an institutional building (e.g. city council) where citizens could be informed about the project and register as users, getting a card in the moment.

Once registered, each user would be able to use the smart containers.

The first step to use the smart container will be to be identified as user, after that, the system will provide the user a **label**, which should be fixed on the bag. The system will automatically associate the label code to the user, to be able to track each bag for the sampling and sorting process. This information will be stored in the container CPU and periodically sent to the PlastiCircle platform. For additional labels it will be necessary to identify the user again. The system will also send a warning signal to the PlastiCircle platform when the number of labels available descends below an established limit, in order to replenish the dispenser.

Labels dispenser will be designed taking into consideration the cleaning process of the container (e.g. pressurized water). For that reason, the dispenser will include some protection elements, such as an encapsulated system or an electromagnetic closure of the slot.

The container will register the information about the **filling status**. For that purpose, a commercial filling ultrasound sensor will be used. Although a commercial alternative selected, this solution should be flexible in order to send the information to PlastiCircle platform, without including a different storing platform (provided by the sensors' company). This is important in order to associate registered information to the developed routing system. Data provided by the filling sensor will be associated to the percentage of filling, establishing a limit for which it is considered the container as 'full'. Information about filling levels should be register in the platform prior to the routing calculation.

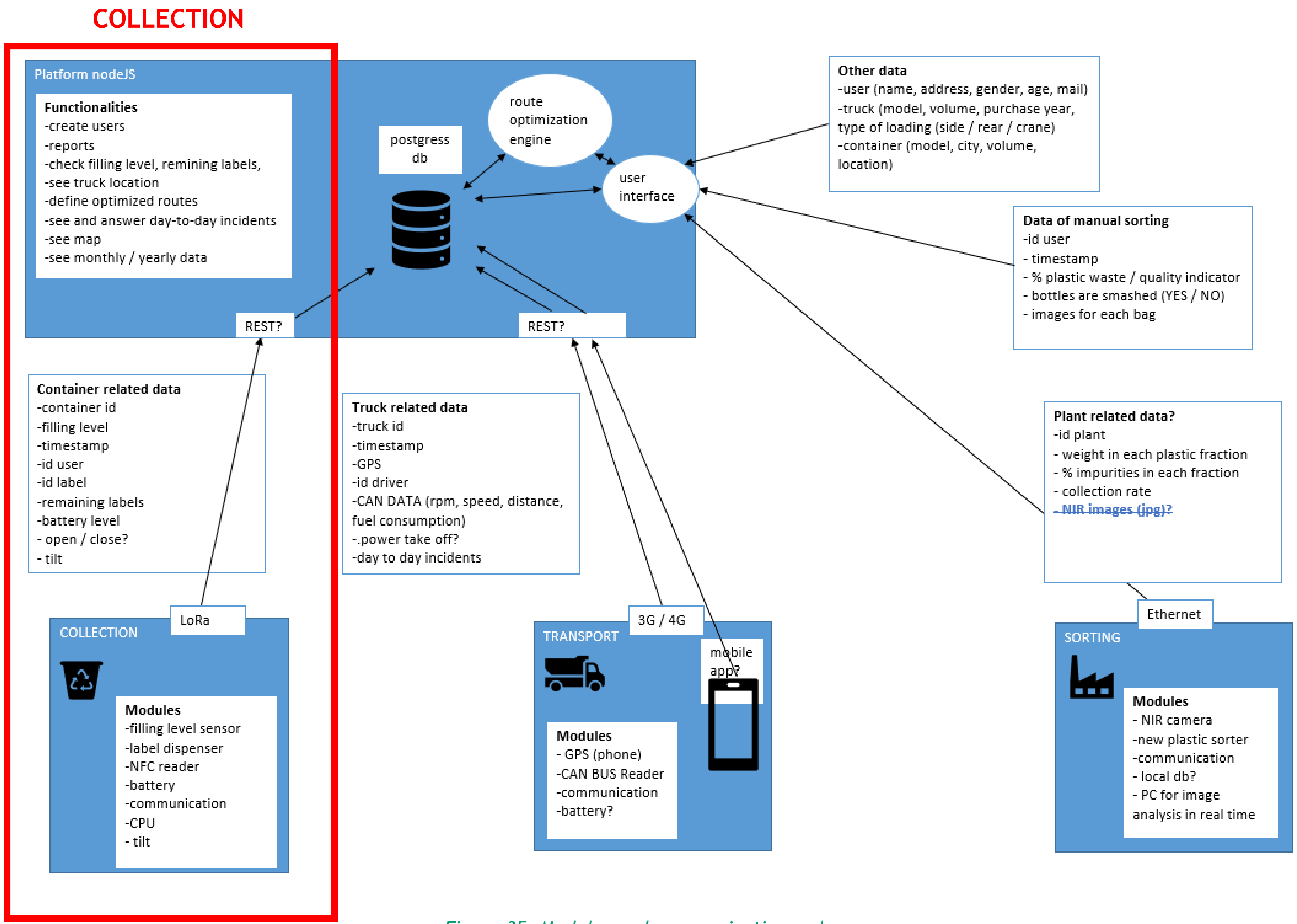

Figure 35. Modules and communications scheme

In addition, selected commercial filling sensor will also include an overturning detector and a temperature detector, to measure risk of fire. It is important to consider **anti-vandalism measures** in the container development. For that purpose, the physical elements will be designed as integrated as possible with the container body (e.g. external elements will be minimized). Also fixing elements will be designed in order to minimize theft or damage risk.

In order to provide energy to the different components, the smart container will include a **battery**. The system will register the level of the battery and will send an alert to the PlastiCircle when the level is below 15%. The batteries should be easily changed to be charged in the waste management company facilities.

Container will periodically communicate with the PlastiCircle platform using **LoRa** system. Periodicity of data transmission needs to be stablished in order to fulfil requirements of the different components of the smart container. Information to be transmitted to the platform includes:

- Filling level of the container
- User information
- Internal temperature
- Tilt
- Number of labels available
- Battery level

The integration of the different modules included in the PlastiCircle project will be essential for the well-performance of the system. Modules will communicate through the common platform which will integrate collection, transport and sorting information (including sampling and manual sorting for incentive procedures).

4.2 Type of container

Herebelow are the features of the standard container use for the collection (Valencia).

Model		3200
Nominal capacity (litros)		3200
Nominal load (kg)		1280
Total width container (mm)	A	1880
Maximum width in the upper area of the container (mm)	B	1760

Width between side boxes (mm) (lifting device)	C	1760
Total depth container (mm)	D	1520
Total height container (mm)	E	1755
Load side height of user side (mm)	F	1200
Height of the loading edge of the street side (mm)	G	1340
Elevation axis distance to user side loading edge (mm)	H	770
Elevation axis distance to load edge street side (mm)	I	815
Standard pedal height to the ground (mm)	L	223(1)
Minimum opening lid user pedal operation (mm)	J1	500
Maximum opening of the user side cover (mm)	J2	550
Maximum opening side street lid (mm)	K	1425
Minimum discharge opening (mm)	M	980
Total empty weight of the container (kg)		150

(1) hauteur de pédale standard. Il existe une version à pédale de 150 mm de hauteur pour le montage du conteneur bas niveau

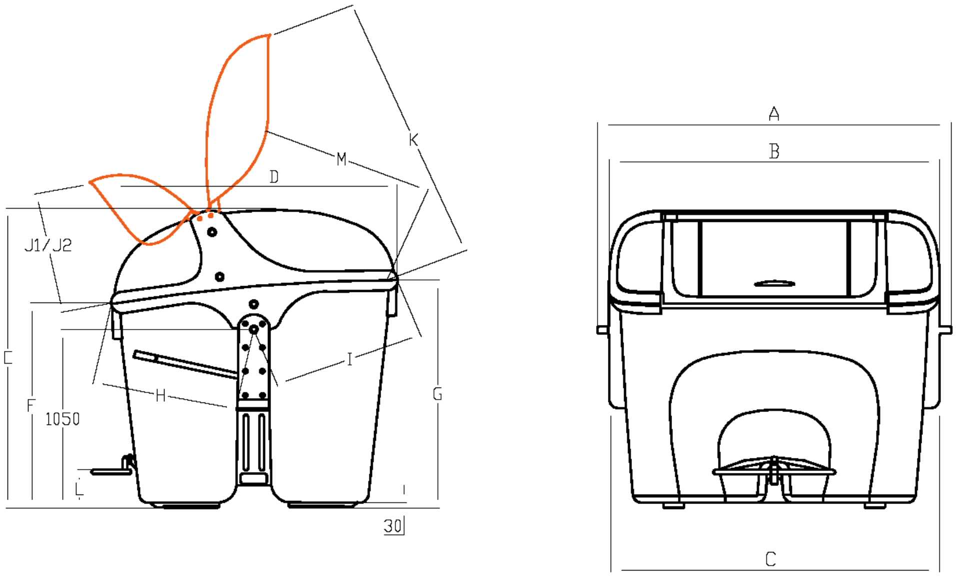

Figure 36. Standard container use for the collection (Valencia)

4.3 List of materials

Regarding the physical component of the smart container, after analysing different market solutions and development kits, initially, it has been selected as main CPU device an **Arduino UNO Rev.3** board.

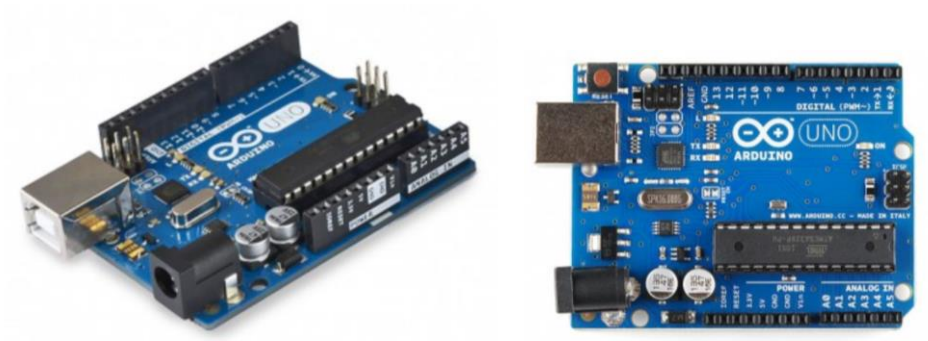

Figure 37. Arduino UNO Rev.3[15]

Arduino Uno is a microcontroller board based on the ATmega328 (datasheet). It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button.

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[15] https://www.cooking-hacks.com/arduino-uno

It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started.

The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega16U2 (Atmega8U2 up to version R2) programmed as a USB-to-serial converter.

Revision 2 of the Uno board has a resistor pulling the 8U2 HWB line to ground, making it easier to put into DFU mode.

Revision 3 of the board has the following new features:

- Pinout: added SDA and SCL pins that are near to the AREF pin and two other new pins placed near to the RESET pin, the IOREF that allow the shields to adapt to the voltage provided from the board. In future, shields will be compatible both with the board that use the AVR, which operate with 5V and with the Arduino Due that operate with 3.3V. The second one is a not connected pin, that is reserved for future purposes.
- Stronger RESET circuit.
- Atmega 16U2 replace the 8U2.

Specifications:

- Microcontroller ATmega328
- Operating Voltage 5V
- Input Voltage (recommended) 7-12V
- Input Voltage (limits) 6-20V
- Digital I/O Pins 14 (of which 6 provide PWM output)
- Analog Input Pins 6
- DC Current per I/O Pin 40 mA
- DC Current for 3.3V Pin 50 mA
- Flash Memory 32 KB of which 0.5 KB used by bootloader
- SRAM 2 KB
- EEPROM 1 KB
- Clock Speed 16 MHz

For the proper working of the board, a battery will be connected to it. For this case, the most commonly used batteries are Li-Ion rechargeable batteries. For the smart container development, it has been chosen a 4 x 3,4 Ah battery, which should provide energy for minimum one week of use of the container. The process and programming will be optimized in order to extend the duration of the batteries as much as possible. The battery is expected to be removed from the container (and changed for a charged one) for charging purposes.

Figure 38. Li-Ion battery for Arduino UNO.[16]

Arduino board allows to connect different peripheral devices. According to the components needed, it would be necessary to add a LoRa connection. For this purpose, a connectivity kit has been selected (LoRa 868 Extreme Range Connectivity Kit)

The **LoRa Extreme Range Connectivity Kit for Arduino**, Raspberry Pi and Intel Galileo includes:

- 2x SX1272 LORA MODULE FOR ARDUINO, RASPBERRY PI AND INTEL GALILEO - 868 MHZ [XBEE SOCKET]
- 1x WASPMOTE GATEWAY SX1272 LORA MODULE SMA 4.5 DBI - 868 MHZ
- 1x MULTIPROTOCOL RADIO SHIELD FOR ARDUINO, RASPBERRY PI AND INTEL – GALILEO
- 1x Starter Kit
- 1x Starter Kit Box
- 1x "Starter Kit" Sticker
- 1x Arduino Jumper Cables
- 1x Breadboard clear
- 20x Resistor 1/4W 5% 220 ohm
- 10x Resistor 1/4W 5% 100 ohm
- 10x Resistor 1/4W 5% 10 K
- 10x Resistor 1/4W 5% 4,7 K

[16] www.geekfactory.mx

- 10x Resistor 1/4W 5% 1 M
- 2x Potentiometer 10K
- 4x Push Button 12x12 B3F-4150
- 1x Temperature Sensor (MCP9700)
- 10x 5mm Red Led
- 10x 5mm Green Led
- 1x 9v To Barrel Jack Adapter
- 1x LDR Sensor
- 4x Sugus
- 1x Piezo Speaker (ref.10066)
- 1x 5mm Triple Output Led RGB (Common Anode)
- 1x 9G Micro Servo
- 1x Hobby Motor
- 1x LCD 16*2 Characters - Green Yellow back light
- 1x Transistor BC547CG

Libelium currently offers two options of this type of radio technology: LoRa and LoRaWAN

- LoRa contains only the link layer protocol and is perfect to be used in P2P communications between nodes. LoRa modules are a little cheaper that the LoRaWAN ones. It works in the 868 and 900MHz bands. Go to the LoRa Tutorial.
- LoRaWAN includes the network layer too so it is possible to send the information to any Base Station already connected to a Cloud platform. LoRaWAN modules may work in the 868/900/433MHz bands. Go to the LoRaWAN Tutorial.

Figure 39. LoRa Extreme Range Connectivity Kit for Arduino[17]

The hobby motor included in the LoRa kit could be used for the activation of the label dispenser. Additionally, some label rolls would be needed. There are many different providers of label rolls, as an example, MIBILS offers **pre-printed waterproof permanent adhesive labels with bar codes**.

Characteristics:

- Waterproof bar codes
- Stain resistant resin ink
- Permanent acrylic pressure-sensitive adhesive labels
- Preprint
- Scannable
- Consecutive numbering

They allow different kinds of bar codes:

- Code 39
- Code 128
- EAN-8
- EAN-13
- UPC-A
- QR Code

[17] https://www.cooking-hacks.com/lora-extreme-range-connectivity-kit

Figure 40. MIBILS pre-printed labels.[18]

In addition, an NFC will be needed for the user identification module. In this case, **RFID 13.56 MHz Module** for Arduino, Raspberry Pi and Intel Galileo seems to be the best option taking into consideration the compatibility with the rest of modules.

RFID (Radio Frequency Identification) is a technology that uses electromagnetic fields to identify objects in a contactless way; it is also called proximity identification. There are 2 elements in RFID communications: the RFID module (or reader/writer device) and an RFID card (or tag). The RFID module acts as the master and the card acts as the slave; this means the module queries the card and sends instructions to it. In a normal RFID communication, the RFID module is fixed and the user takes his card near it when he needs to start the interaction.

- Chip: PN532 by NXP.
- Compatibility: Reader/Writer mode supporting ISO 14443A / MIFARE /
- FeliCaTM / NFCIP-1
- Distance: 5cm
- Max capacity: 4KB
- Tags: cards, keyrings, stickers
- Applications:
- Located based services (LBS)
- Logistics (assets tracking, supply chain)
- Access management
- Electronic prepaid metering (vending machines, public transport)
- Smartphone interaction (NFCIP-1 protocol)

[18] http://www.misetiquetas.com/print-labels/invariable-data-label-printing/preprinted-permanent-adhesive-waterproof.html

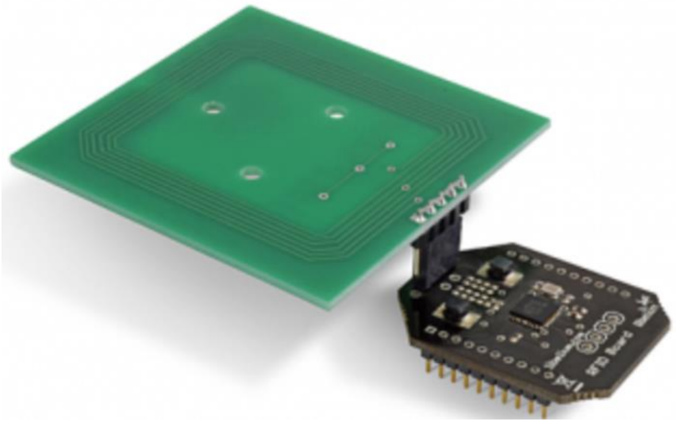

Figure 41. RFID 13.56 MHz Module for Arduino, Raspberry Pi and Intel Galileo[19]

Finally, a commercial filling level sensor will be used. This one still needs to be defined.

[19] https://www.cooking-hacks.com/rfid-13-56-mhz-nfc-module-for-arduino

Conclusion

The different models and systems used in the selective collection of plastic waste have been presented and analysed in this deliverable. The innovative tools and procedures in the field of information and communication technologies applied to the collection of this fraction, such as user identification and closure systems in the containers are showed also, in the smart city environment. It has been compiled and updated, therefore, in a single publication, the current existing design of a plastic waste collection system highly technified and oriented to the citizen. This has been essential for the subsequent design of the mechanical-procedural system object of the WP2 to which the present deliverable belongs.

The chapter dedicated to review the state of the art in the pilot cities, shows that collection systems are different in each of the cities and that the use of the user identification technologies is only implemented (with limitations) in Utrech.

Regarding the actions to improve the quality of the recovered material (i.e. with the lowest percentage of improper fraction), again the Dutch city stands out as the most active, putting into circulation the use of transparent bags, which allow viewing the content. This has been possible thanks to the personalized collection system (door to door) used in the city. Finally, there are not mechanisms or policies of reward deployed to date in the three cities based on the civic behaviour of citizens of separating waste or its generation.

The following conclusions have been obtained regarding the requirements of the smart container:

In terms of communications, the most appropriate system is Sigfox for Utrech and Valencia as there is coverage in both cities. This technology is more appropriate than 3G as it has lower battery consumption and lower communications costs. In the third location Alba-Iula, the implementation of SigFox is not possible, which opens the way to deploy LoRa technology in this locality. This will allow to compare the results obtained by the two European technologies. 3G has been discarded, as it is an outdated system for the use of M2M communications.

While carrying on this part of the project, we faced some limitations. One of them is the difficulty to define precisely at this stage the components that will be used. Indeed, the solutions envisaged must be tested to see if they meet the requirements of the project in practice. The solutions discussed in this document may therefore be subject to change at any time. Another limitation is the necessity to find a versatile solution that can accommodate to all kind of containers. It is then necessary to take into account much more elements so that the solution can be suitable for each model, not only pilot cities but also adaptable to other systems.

Regarding the waste identification system, although the current technological applications in the market have been analysed, it has not been possible to determine the initial solution that will be used in the design of the container, therefore the initial objective has not been met. This is due that the washing of the container (inside a container washing truck) is a critical factor when designing the electro-mechanical system. To deal with this risk, the following options are considered:

- Use of bags with printed bar codes
- Use of pre-printed labels
- Installation of the printing system in premises

The final solution for the waste identification together with the components to be used in the design will be defined in the subsequent deliverable.

Finally, regarding the user identification system, it has been determined that NFC is the most appropriate technology as this technology allows the user identification by both cards and mobile phones.

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PlastiCircle
TOO VALUABLE TO WASTE

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