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Transforming Supply Chain Management for Bio-waste: a Whitepaper on Proof of Location

ubiwhere

NGI TRUBLO

Introduction

The European Commission's environmental policy[1] aims at protecting the environment and human health and helping the EU transition to a circular economy. The EC considers it crucial to manage waste in an environmentally sound manner and use the secondary materials they contain.

The latest metrics indicate that the average European produces five tonnes of waste every year, with only 38% of such waste being recycled. In addition, in some countries, over 60% of household waste still goes to landfills, where it decomposes and produces greenhouse gas emissions. The primary goals are to improve waste management, stimulate innovation in recycling and limit landfilling; however, certain categories of waste require specific approaches.

One such category is Bio-waste, also known as biological or biodegradable waste. Bio-waste includes waste materials from living organisms, such as food, yard, animal, and sewage, but does not contemplate residues from forests or agriculture activities or other waste, such as natural textiles, paper or processed wood. Bio-waste is typically rich in nutrients and organic matter, which makes it an ideal candidate for composting and other forms of organic waste management. Recycling bio-waste can help reduce the amount of waste sent to landfills, conserve natural resources, and provide valuable nutrients for soil and plants. Its main environmental threat is methane production from its decomposition in landfills, accounting for 3% of the total greenhouse gas emissions in the EU-15 in 1995.

Bio-waste from kitchens can be treated in several ways, depending on the specific waste management system. While these vary depending on the community, some standard methods exist across the EU. One common method is composting, which involves breaking the organic matter into a nutrient-rich soil amendment that can enrich soil and support plant growth. Another method is anaerobic digestion, which uses microorganisms to break down the organic matter without oxygen, producing biogas (for energy) and a nutrient-rich fertiliser.

Overall, the collection, separation, and treatment of bio-waste from kitchens are essential to help reduce the organic waste's environmental impact and support the sustainable usage of resources.

[1] Waste and Recycling | European Commission (Environment)

The collection and separation must be effective and efficient; otherwise, the decomposition of bio-waste will spoil the results expected from the treatment procedures.

Collection

Municipal waste collection services typically collect bio-waste from kitchens as part of a regular curbside collection or through dedicated organic waste collection programs. In some cases, households also have the option to deliver their bio-waste to a composting facility or drop-off location.

Separation

Bio-waste from kitchens can be separated from other types of waste through various methods, including using separate bins or bags for organic waste or specialised food waste disposers in the kitchen. In some communities, compostable bags are provided to households to make the separation of bio-waste easier.

The *"Green Paper on the management of bio-waste in the European Union"*[2] mentions that separate collection schemes have functioned successfully in many countries, especially for green waste. The paper states, *"In all regions where separate collection has been introduced, it is regarded as a successful waste management option"*. Its benefits include generating a cleaner bio-waste fraction (diverted from the landfills) that produces high-quality compost and facilitates biogas production.

However, setting up separate collection schemes brings challenges, including re-designing waste collection systems and changing citizens' habits. Even if they are not more expensive[3], their proper design and management require higher effort than mixed waste collection systems.

[2] Green Paper on the management of bio-waste in the European Union {SEC(2008) 2936}

[3] Optimised separate collection systems may substantially reduce the frequency of collection of residual waste, also savings on disposal may be considerable. See e.g. Favoino, 2002.

Ubiwhere has developed a technological solution called SmartPAYT[4] that supports municipalities in separating and collecting bio-waste. Compliant with the EU's environmental policies, SmartPAYT is a software platform to implement behavioural changes and overcome waste management challenges.

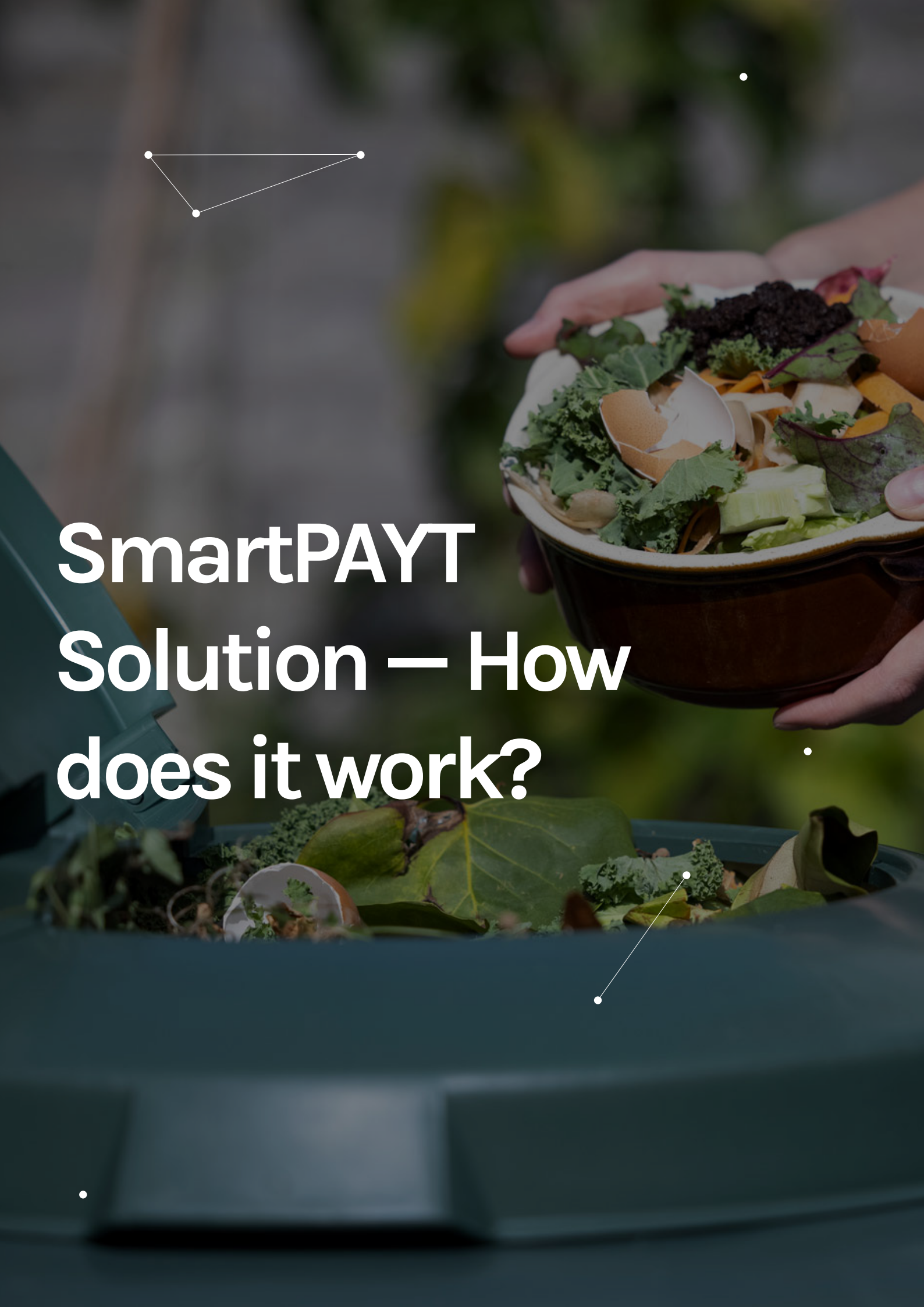
With SmartPAYT, waste containers are retrofitted with access control devices to track how much bio-waste is separated and offer citizens an active part in the sustainable transformation of their cities. SmartPAYT enables municipalities to digitise and optimise the collection of biowaste (for treatment) to audit the operations performed by waste collection companies.

However, how can public authorities trust and validate the location shared by the waste collection companies if they can spoof data from Global navigation satellite systems? This whitepaper aims to explain how dynamic proof of location can be used in this realistic use case, showing the results developed within the POSER project[5], with funding from NGI Trublo[6].

[4] Ubiwhere's solution for circular economy and waste management in one place

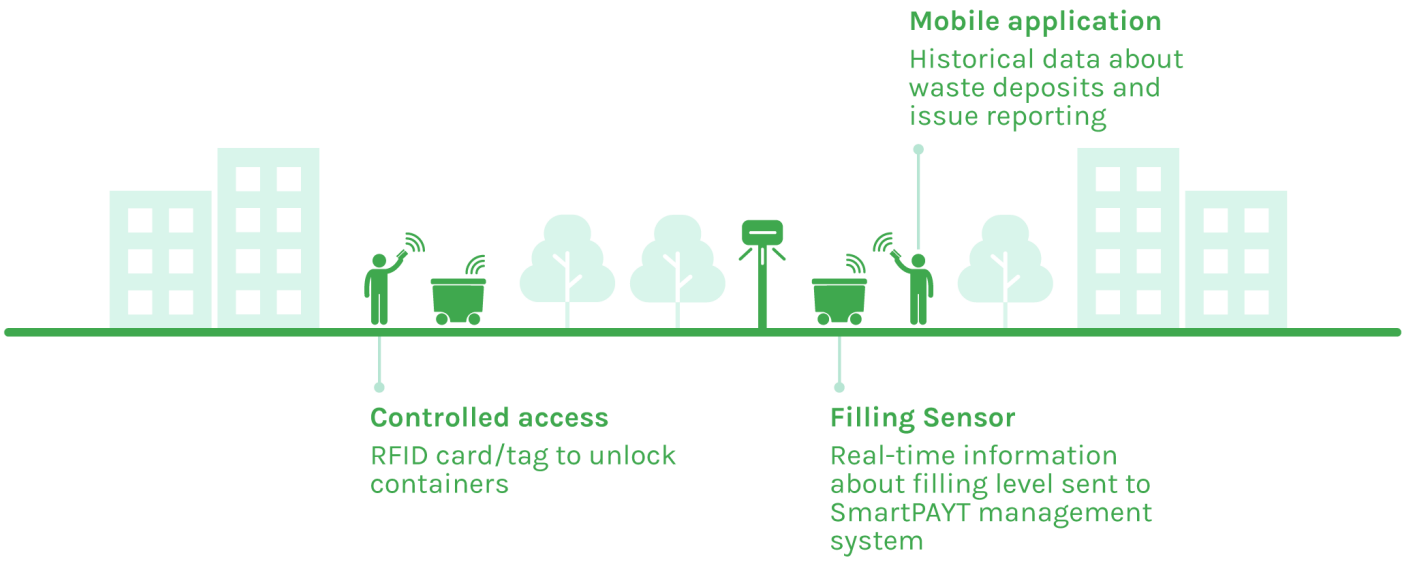
[5] POSER - Dynamic Proof of Location

[6] NGI Trublo - Distributed Trust



SmartPAYT Solution — How does it work?

SmartPAYT is a technological solution aimed at helping reduce the environmental impact of bio-waste and encouraging individuals to take more responsibility for waste generation and management. Based on digital equipment, this solution enables controlled access to waste containers to digitise the amount of garbage thrown away.



Radio-frequency identification (RFID) devices allow access to waste containers and track the number of deposits in each bin. This data is then analysed for two purposes: to motivate citizens to reduce waste production with the PAYT (Pay-As-You-Throw) model or to reward them for separating it with the RAYT (Receive-As-You-Throw) model.

Although the technology components and modules used in SmartPAYT can vary depending on the specific implementation and customer requirements, some standard ones are the following:

Waste Containers
Are equipped with technology such as RFID tags and RFID devices to control access to the bins and measure the amount of waste deposited. These containers may come in different sizes or colours, with each size or colour corresponding to different types of trash.

Data Collection and Management Platform
The web platform is responsible for the management operations on the devices that perform access control to data visualisation insights and reports about sustainable behaviours. The platform captures data from waste containers and other applications (described below). It stores the information for analysis, which involves generating reports, delivering dashboards, and using data visualisation tools to inform decision-making teams. Based on the data and insights, city authorities may implement adjustments to optimise logistics operations and increase the sector's efficiency.

Communication and Connectivity
SmartPAYT requires communication and connectivity components to read RFID tags, unlock the waste containers and transmit the data from the containers to the data collection and management platform (running on the cloud). This capability involves wireless communication technologies such as cellular or other protocols and connectivity options, depending on the customer's requirements.

Mobile Applications for citizens and technicians
SmartPAYT is also composed of technology components for education and outreach efforts, such as websites, online portals, or mobile applications, to provide information to residents or businesses about the system, its objectives, and how to participate and comply with waste management policies properly.

- Citizens can use SmartPAYT mobile application to monitor their behaviour patterns and get insights on reducing and separating waste by receiving incentives and rewards.

- Technicians and City Authorities use SmartPAYT mobile application to onboard the community in a friendly way and deliver them the RFID tags or cards, as well as for maintenance and installation operations of the waste containers and hardware equipment.

- Waste collection companies use the mobile application to scan the RFID tags of the waste containers and record the amount of bio-waste collected when they perform the (collection) routes.

Within the POSER project development and pilot demonstration, the focus is on SmartPAYT's capabilities and features for the waste collection operations performed by (waste collection) companies, concretely for biowaste.

In Europe, the typical waste collection can vary depending on the country, region, and local regulations but generally follows similar principles and practices. It is typically done with specialised vehicles designed to collect and transport waste from containers, bins, or bags placed at designated places for residents or businesses. These vehicles can be equipped with compartments to collect different types of waste, such as general waste, recyclables, and organic waste, to prevent cross-contamination. They often follow predetermined schedules where it is fetched on specific days or timeframes. These schedules vary depending on the location and type of waste, especially regarding biowaste.

As mentioned, SmartPAYT delivers a mobile solution (a hardware device installed inside the truck's cockpit) for digitising biowaste collection operations. Equipped with an RFID reader, the "truck kit" is programmed to read the RFID tags that identify each waste container or bag when they are collected (or picked up). It then leverages its connectivity and sensors to retrieve the current location. It sends all this data to SmartPAYT's web platform for database storage and further analysis. Given that anyone can spoof GPS data, how can SmartPAYT customers trust the location data sent by this kit and third-party organisations hired for the waste collection?

The motivation behind the change of scope in POSER.

Ubiwhere's original idea for POSER was related to sustainable mobility. Concretely, Ubiwhere aimed to develop further a solution called GoGreen, capable of delivering incentives (discounts, bonuses, rewards) to citizens that opted for reducing their carbon footprint and taking greener mobility solutions (such as riding public transportation, shared mobility, biking or walking). POSER would enrich GoGreen with Proof-of-Location mechanisms to ensure that the crowd-sourced location is authentic by performing triangulation with other infrastructure (LoRA antennas) and not relying purely on the data shared by the mobile devices (GPS). However, Ubiwhere quickly found limitations on the scalability and market acceptance, given the lack of entities to invest in community habit-changing at the regional, national or European levels. In parallel, SmartPAYT was gaining traction because it offers several benefits to waste management companies and consumers, such as:

Incentivise waste reduction
By encouraging citizens to produce less waste, sort and recycle more, and compost organic waste. SmartPAYT encourages citizens to be more mindful of their waste generation and disposal practices, reducing overall waste generation by making citizens more aware of the cost of their waste disposal.

Improve recycling rates
By encouraging consumers to separate waste properly, which leads to increased recovery of biowaste, which can generate revenue for waste management companies in the circular economy.

Better resource management
SmartPAYT can help city authorities and waste companies manage their resources, including collection vehicles, staff, and equipment. By optimising collection routes and schedules based on the amount of waste generated in specific areas, SmartPAYT can reduce transportation costs, fuel consumption, and greenhouse gas emissions.

Increased transparency
SmartPAYT can provide greater transparency and accountability in waste management operations. By tracking the amount of waste generated and disposed of by each citizen, SmartPAYT helps identify areas where waste reduction and recycling efforts are needed, leading to more effective waste management practices.

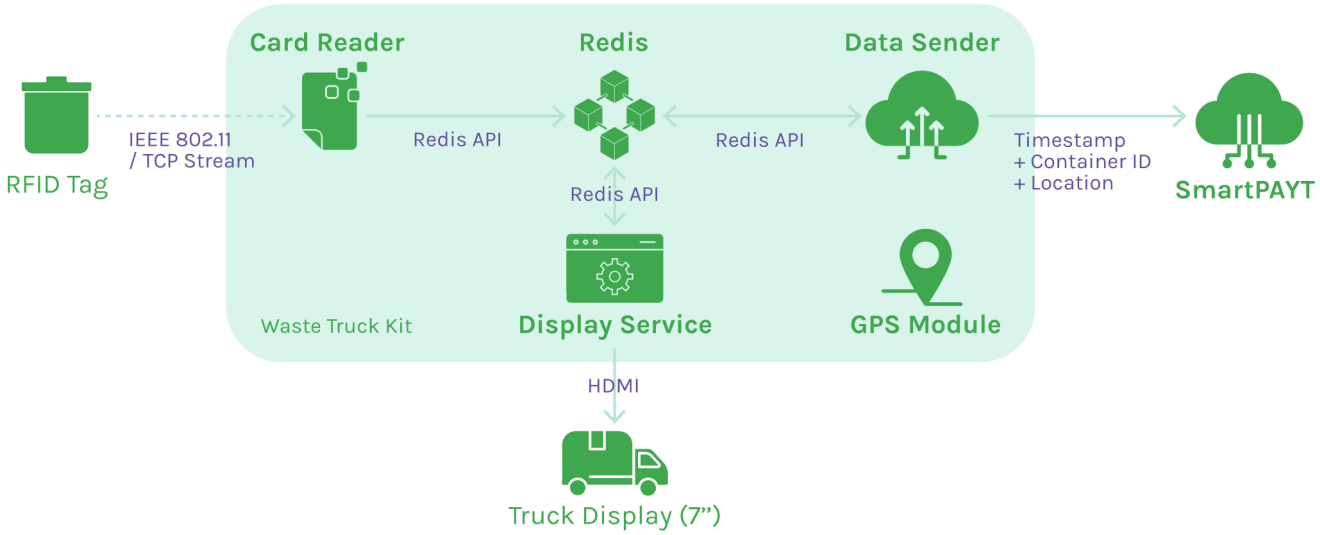
Recent studies have shown that we can take advantage of biowaste's beneficial, environmental and economic potentials when humans selectively collect it and send it for treatment and recovery. Bio-waste appears whenever we prepare a meal and dispose of food remains, representing, on average, almost 37% of our "common garbage" bin. We can therefore avoid pollution by separating and valuing bio-waste, as this organic waste has much value when treated correctly. Thus, investing in prevention and selective collection contributes to several objectives, and not only concerning meeting European diversion or recycling targets.

For the entities responsible for municipal urban waste management systems, the General Waste Management Regime determines that the selective collection of bio-waste must be in operation by December 31, 2023. To this end, these entities must adopt the necessary measures to:

- Enable the separation and recycling at the source of bio-waste through domestic or community composting and other local recycling solutions;
- Ensure selective collection and subsequent transport to recycling facilities for composting and anaerobic digestion, avoiding mixing in treatment with other waste, particularly with the organic fraction of undifferentiated waste.

The entities responsible for municipal urban waste management systems are the target customers of the SmartPAYT solution. These typically (sub)contract collection and transport services to the final destination of urban solid waste and urban cleaning in the municipalities, which need to ensure that the collection is carried out with specific periodicity, taking into account the deposits made by the citizens to guarantee that the bio-waste is made the most of in the recycling and composting process and is not wasted through deterioration or damage.

Within the scope of POSER, Ubiwhere adapted the waste collection truck kit from SmartPAYT to use existing LoRA infrastructure and triangulation algorithms to ensure the proof of location obtained by the hardware kit and guarantee greater trust between the entities involved. The following images showcase the architecture and demonstration of SmartPAYT's waste collection truck kit before the POSER project.



The changes required for POSER concerned the location retrieval of the truck not only by the GPS device but also with the Helium network to integrate a decentralised proof of location. The Helium Network is a decentralised wireless network specifically designed for IoT devices. One of its unique features is using a wireless protocol called LongFi, based on the LoRaWAN protocol, which allows any LoRaWAN-compatible device to connect to the Helium Network, making it an ideal choice for a wide range of IoT applications.

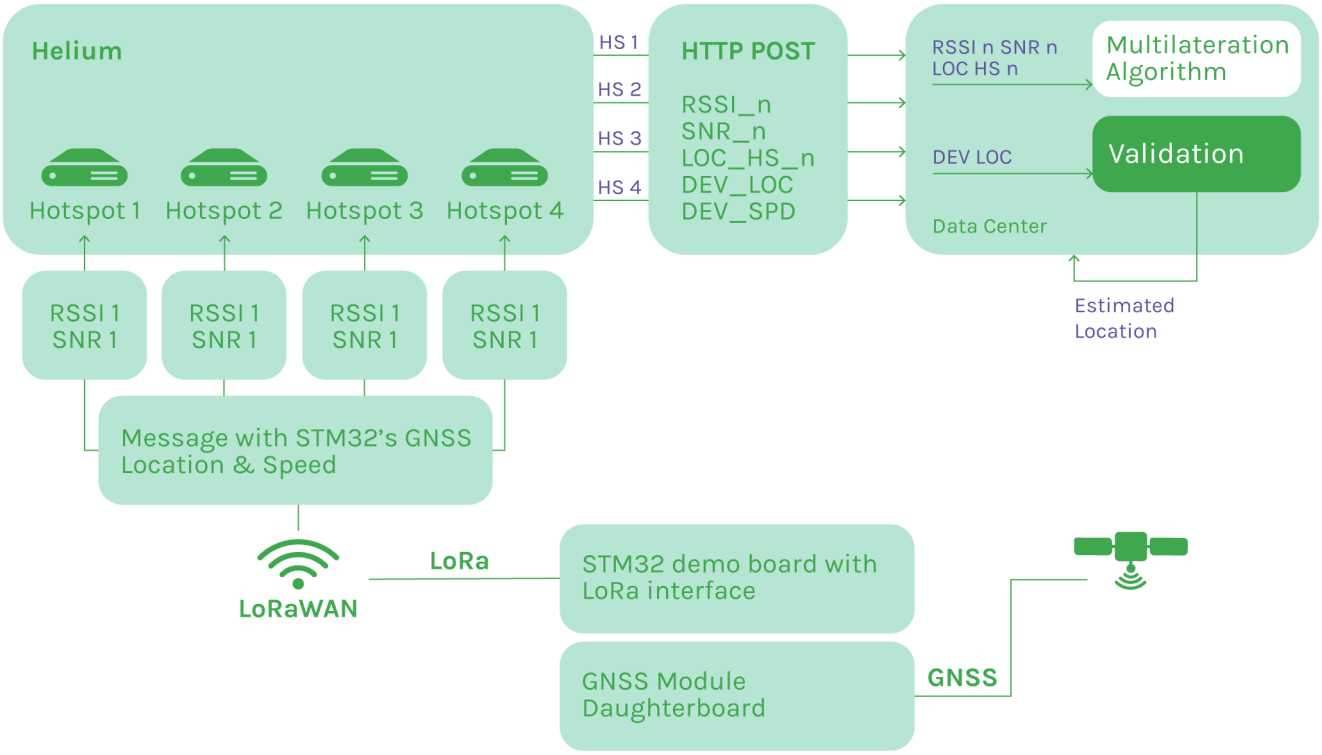
LoRaWAN is a low-power, long-range wireless protocol designed specifically for IoT devices. It operates on an unlicensed radio spectrum and has a good range in rural and urban environments. LoRaWAN is often used for applications such as smart cities, smart agriculture, and asset tracking, where long-range connectivity and low power consumption are essential. The Helium Network integrates with LoRaWAN devices by providing a network infrastructure that enables these devices to connect to the Internet and communicate with other devices on the network. Helium Hotspots are the access points that provide coverage for the Helium Network, using a combination of LoRaWAN and cellular technologies to connect to the Internet and transmit data.

Proof of location is a crucial feature of the Helium Network, which ensures that Hotspots provide coverage in the areas where they are needed. Hotspots must verify their location periodically by sending cryptographic proof of their coordinates to the Helium blockchain. This proof of location is generated using a combination of GPS, Wi-Fi, and Bluetooth signals, which are used to verify the Hotspot's physical location. Using this proof of location mechanism, the Helium Network ensures that Hotspots provide coverage in the areas where they are needed, which helps ensure reliable connectivity for IoT devices. Additionally, Hotspot owners are rewarded with Helium tokens for providing range, incentivising them to maintain and expand the network.

Results of the change

Our whole system is based on the premise that GNSS location is precise but untrustable (because GNSS can be spoofed). In contrast, the LoRaWAN location is imprecise but trustable (as there is a blockchain-type relation of trust between different hotspots). Unfortunately, the imprecision range (> 1 km) makes the system impracticable for the desired purposes. We have thus decided to design our solution as simple as possible by using only one LoRaWAN client module, working together with a GNSS receiver and the network of Helium Hotspots.

Since this approach would be vulnerable to a GNSS spoofing attack, we opted to use the alternate method of LoRaWAN hotspot multilateration for a precise location. Multilateration is a technique used to determine the position of an object or signal by measuring the time it takes to reach multiple known locations. In multilateration, the time delay or time of arrival (TOA) of a signal is measured at each known location. The differences in these times are used to calculate the distance between the object and each known location. Once the distances are available, the position of the object or signal can be determined using geometric algorithms, such as trilateration.



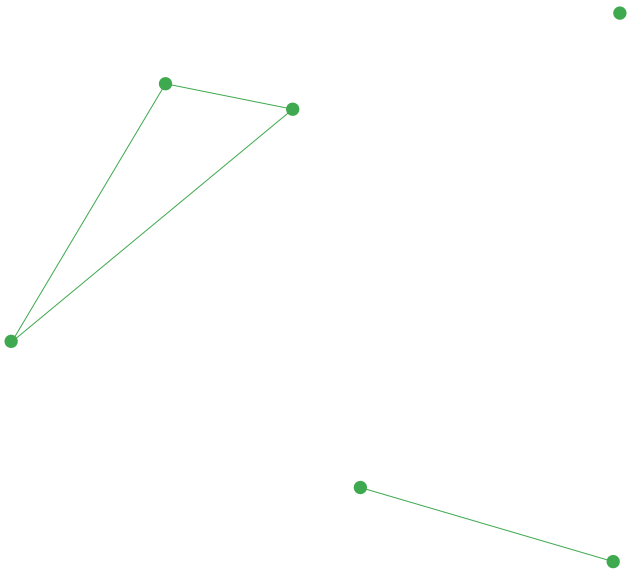
Rather than using the truck's device as the means of location, we have integrated a low-power location tag with the truck's kit, made of one STM32 LoRa module connected to a GNSS receiver, to determine the precise location. SmartPAYT solution thus ends with two location measurements, one of which is accurate but untrustworthy, and another imprecise but trustworthy. Both locations reach our web application, which then compares both measurements to check whether the precise GNSS location is plausible (i.e., within the range of error of the LoRaWAN location). If they diverge to the point that they are incompatible, the GNSS location is deemed false and most likely to have been spoofed. If, however, the GNSS location is compatible with the LoRaWAN location, then the GNSS location is considered both precise and just as trustworthy as the LoRaWAN location.

Conclusion

POSER showed the capability of ensuring the needed trustworthiness of location data shared by mobile devices, initially envisioned and tested with GoGreen. Given Ubiwhere's focus on the SmartPAYT solution and its relevance for urban societies and Europe in general, we felt the need to integrate the Proof of Location algorithms with this product aimed at reducing biowaste's environmental impact and enhancing circular economy.

Combining the two solutions helps municipal waste management to be more efficient and eco-friendlier. In that way, Ubiwhere adapted the Smart PAYT truck kit to use existing IoT infrastructure (LoRA hotspots) and triangulation algorithms to ensure the proof of location obtained by the kit and greater trust between the entities involved. Future customers of Smart PAYT will get insights from the field-tests done in aveiro and be able to integrate this solution in their (bio-)waste collection routes.

The results achieved our expectations, since we were able to develop an SDK (Software Developing Kit) that validates the location shared by a mobile device, based on the network of Helium hotspots to demonstrate that dynamic proof of location is beneficial for smart city solutions such as Smart PAYT. To sum up, it helps ensuring that bio-waste is effectively collected in the appropriate times (in a trustworthy manner) and avoiding that it deteriorartes or gets damaged, so as to retrieve optimal results from the recycling and composting processes.



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