A Smart Bin Implementantion using LoRa

Dimitrios Ziouzios
Department of Electrical and Computer Engineering
University of Western Macedonia
Kozani, Greece
dziouzios@uowm.gr

Minas Dasygenis
Department of Electrical and Computer Engineering
University of Western Macedonia
Kozani, Greece
mdasyg@ieee.org

***Abstract*— Cleanliness is a crucial matter for modern cities. The overflow of garbage in public areas creates unhygienic condition and it may induce numerous diseases to the population. In order to avoid all this negative reasons, τhe bins and the garbage management must be modernized using the Internet of Things (IoT). In this paper we proposed a 'Smart Bin Management System' to cover this need. Using a microcontroller and ultrasonic sensors we can estimate the level of garbage and making use of Lora technology. All the information will be stored in an Information System (IS) where the users can monitor each bin and be notified for emergency incidents. Using this IS the users have all the data they need to manage the garbage collection efficiently. Finally, compare to other implementations our project is the first that utilizes the LoRa protocol which is decreases the overall budget and increases the communication distance.**

***Keywords*—Smart cities, Ultrasonic Sensor, Microcontroller, LoRa, Information System**

I. INTRODUCTION

Due to the 2018 Revision of World Urbanization Prospects produced by the Population Division of the UN Department of Economic and Social Affairs (UN DESA) today the 55% of the world's population lives in urban areas, a proportion that is expected to increase to 68% by 2050 [15]. One of the major problems that is looming is the urban garbage. It is common to see overfull garbage bins on the streets and especially on summer months the problem is aggravated because of the heat and the bad smell of the decomposition. According to the World Bank's review report [1], in 2012, the global Municipal Solid Waste (MSW) generation levels were around 1.3 billion tons per year. This figure is expected to reach 2.2 billion tons per year by 2025[1].

Current waste management trends are not sophisticated enough to achieve a robust and efficient waste management mechanism. Although, the garbage collection is consistent, the current collection does not allow the local municipal to know the occupancy of each garbage bin if it is full or empty. Traditionally, garbage bins are emptied at fixed schedule by the cleaning agents. This way has some disadvantages such as: some garbage bins fill up faster than others in the same route and they are overflowed before the next scheduled time for collection, leading to hygiene risks. Also, there are special periods (e.g. festivals, weekends and holidays) when some garbage bins fill up rapidly and there is a need for more garbage collections routes. Keeping a rural city clean is a great challenge and involves several factors such as optimized management of different stakeholders, efficient financial factors, collection & transportation, etc [2][3]. Furthermore, according to [4] the 85% of solid waste management funds are spent on garbage collection and transportation. The operational cost can be reduced by optimizing the quantity and deployment of collection bins and their collection rate [5],[6],[7].

Most of the municipals are trying to tackle this problem by changing the routes, combining a section of route with other routes, placing more bins etc. But all these static solutions are temporary solutions and not valuable in long term due to the continuous increase of the garbage.

Using the Internet of Things (IoT) with a dynamic schedule and route can reduce the collection and disposal cost up to 20% and the transport distance to 26% [8], [9]. For a truly dynamic and automatic system, it is important to know the current and actual garbage fill level, as well as the individual history trend, to derive a prediction on the expected overflow timestamp. In this research, we propose a real-time bin fill level status, utilizing the LoRa (Long Range) network.

Our paper structure is as follows. After the Introduction, is the section II, related work, where we discuss related solutions to the same problem. In section III, we analyze our system and specifically our hardware architecture, software implementation and the connectivity. We present our measurement results in section IV and finally, in section V are the conclusions and finally in section VI the future work.

II. RELATED WORK

In the research work of Baby et al. [10] a machine learning for prediction is described using, Microsoft Azure platform and Microsoft Power BI which are commercial. Furthermore, the communication between each bin and the central information system is achieved via sms which is costly or via the internet which requires internet infrastructure WiFi or GPRS. In both cases for a full city deployment running cost are skyrocketed.

Folianto et al. [11] are proposing a system which is designed to collect data and to deliver them through wireless mesh network. A gateway is installed in a range of cluster nodes and it must communicate through internet to send the data Ethernet, Wi-Fi, GSM. Although the system seems to operate correctly there are plenty of cases where the bins are far away and the mesh network is out of range. Also, another problem is the gateway must connected to the internet and this increases the cost.

Faccio et. al [12], developed a garbage bin using numerous types of sensors as camera, ultrasonic, LED, for pressure etc. with purpose the early detection of the fill status. Also, every single garbage bin has GPRS to communicate with the system. This make the solution economically unprofitable.

Hitesh et al. [13] proposed a real time smart bin, using Arduino and ultrasound range sensor for calculating the fill percentage. The problem to this solution is the connectivity. To send data the system uses Ethernet shield or Wi-Fi shield. If there is no network near a bin then the system is useless. Usually the majority of bins are situated to places without Wi-Fi coverage.

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The research work of Catania et al. [14] is a system which has a sensor at the lid of the garbage bin to measure the fullness of litter and sensor at the bottom to measure the weight of litter. Using a zigbee module, the embedded system sends the data to the nearest data aggregator light pole which connected to a gateway.The gateway is based on a Raspberry PI and collects, process and transmits the data to the Information system. There is no need for a battery because each Raspberry PI is powered by the lamp pole. Also the authors proposed that the bins are powered from the light poles limiting the usefulness only to fixed garbage bins. To transmit the data GPRS or a Wi-Fi are required. This solution can implemented only for bins who are near to light pole. Also, there is a cost of using it because it needs GPRS if there is no Wi-Fi and it carries a GPS which does not make sense in this scenario.

III. OUR SYSTEM ARCHITECTURE

Our system is based on three axes i) hardware, ii) software and iii) connectivity

A. Hardware Implementation

Our system is based on the microcontroller Arduino Uno which has an ATMega328 single-chip, operates with 16MHz clock frequency at 5V and having a typical power consumption 40 to 50 mA. For our project this microcontroller is ideal for collecting the measurements of the sensors and sending them to the Lora Gateway. We selected this microcontroller due to the low power consumption, low price and covering the requirements of our project in cpu performance and memory. The Arduino is connected with the sensors below:

1. Pressure Sensor: For detecting when the cap of bin is opened/closed. When the cap pushes the sensor's trigger it means the cap is closed, otherwise it means it's open.

2. Temperature Sensor: For checking the temperature inside the garbage bin and on an emergency of fire where the Arduino will send notification alert to the system. Usable temperature range: -55 to 125°C and it has ±0.5°C Accuracy from -10°C to +85°C.

3. Sonar: In our project we use an Ultrasonic Sensor HC-SR04, for calculating the fill percentage. We installed the sensor at the top of the bin's cap. Ultrasonic can provide measurement from 2cm to 400cm with 3mm accuracy, which is suitable for common urban garbage bin.

4. Connectivity: Libelium SX1272, for sending the data to the LoRa Gateway. The frequency band is 863-870 MHz in Europe and 902-928 MHz in the US. Transmission power is 14 dBm and the distance that can be covered is more than 22km [19]. We choose LoRa for connectivity because of the long range, the low cost and the low power consumption.

In figure 1 we can see some details of our installation. In the normal case the system is in low power consumption in deep sleep mode. When the user opens the cap of the bin the Arduino Uno wakes up from the deep sleep due to the received interrupt (which is connected to an interrupt enable pin, 2 or 3, of Arduino Uno) from the pressure sensor and it is ready to measure the litter and the temperature. As soon as the cap is closed the measurements are performed and transmitted. Then the Arduino enters deep sleep mode again to save as much energy as it is possible. All the data are stored to a database and our Information System notifies the administrators about the litter fullness and the temperature of the bin.

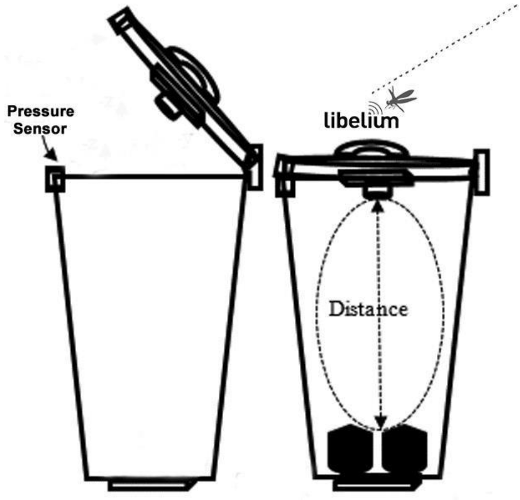

Fig. 1. Hardware implementantion

We opted to take measurements every time the cap opens and closes in order have as much information as we need in real time. It is very useful for the users of our system to know what time a bin is full, in which days and how frequently. Also, it provide us with another important information. We know when the bin emptied. Our Information System gets the data, stores the ID of the bin, the time and the measurements.

B. Software Implementation

For the software implementation we used the Arduino IDE which is very simple and effective. The structure of our software is described in figure 2.

When the cap of the bin is opened, an interrupt sends to Arduino Uno Processor. Arduino waits for the cap to close,in order to take measurements. If the cap closes in 5 minutes the ultrasonic sensor take the metrics and send it via LoRa to the Lora gateway and the data saved to our Information System.

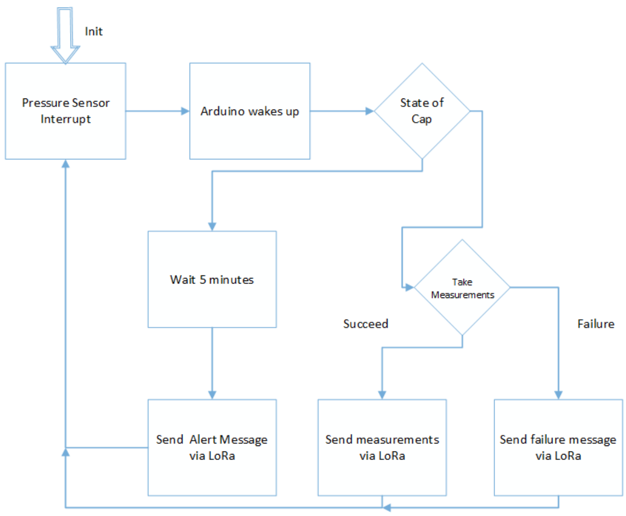

Fig. 2. Stateflow of our system

If the cap doesn't close in 5 minutes the system send an alert to the LoRa Gateway that the cap is opened and it can't take measurements and someone manually must close it. All the data are stored in our Information System where users can see the fill level of the bins and the temperature in real time.

C. Connectivity

Our major difference from other systems is the connection between the bins and the main platform. In our work, we use LoRa [16]. LoRa is a proprietary spread spectrum modulation technique by Semtech and can be used with any MAC layer. LoRaWAN is the proposed MAC which operates a network in a simple star topology.

The LoRa system consists of three main components:

- LoRa End-devices: sensors/actuators connected via the LoRa radio interface to one or more LoRa Gateways
- LoRa Gateways: concentrators that bridge end-devices to the LoRa Net-Server, which is the central element of the network architecture.
- LoRa NetServer: the network server that controls the whole network (radio resource management, admission control, security, etc.).

The innovation consists in ensuring the phase continuity between different chirp symbols in the preamble part of the physical layer packet, which enables a simpler and more accurate timing and frequency synchronisation, without requiring expensive components for generating a stable local clock in the LoRa node. Furthermore, the technology supports variable data rate, thus giving the possibility to trade throughput for coverage range, or robustness, or energy consumption, while keeping a constant bandwidth. [19]

The actual data rate ranges approximately from 0.3 kbps to 11 kbps, however, the system capacity is larger because the receiver can detect multiple simultaneous transmissions from different nodes by exploiting the orthogonality of the spreading sequences used by LoRa. [17]

The advantages of LoRa network are the long distance, the low power consumption and the low cost for installing that network. For our project, this is the ideal solution, because we need a network with those characteristics. Some bins may not be in a Wi-Fi range, or the distance between two bins is too long and the mesh technique cannot be used. Finally, the GSM network increases the running cost and makes is prohibited solution for our project.

IV. MEASUREMENT RESULTS

In our project we used a LoRa gateway which is installed in Kozani at the University of Western Macedonia and it is free for all [18]. The experiments took place from 1st of April to 15th of June in the area of Kozani with random sampling.

In Figure 3 are the results of our measures in different spots in Kozani. The longest distance is 23.27km which is exceptional and more than enough for our project requirements.

V. CONCLUSIONS

This paper presents an integrated smart bin management system for smart cities. The system is based on an Internet of Things model combined with the LoRa Network. Using the sensors the microcontroller collects the measurements and sends them via this network to the server for storage and processing. Using these data we can create the most efficient routes for collecting the garbage and in real time we can visualize the fill percentage on all garbage bins, their temperature and the status of the cap. Our smart bin management garbage collector helps the municipalities to have cleaner cities with no overflow bins and lower the cost of garbage collection.

In our work we use the LoRa network for sending the measurements to the server. The benefits of this network are the long range and the low cost.

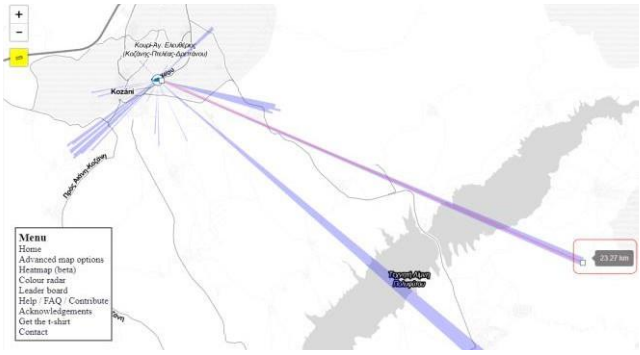

Fig. 3. Measurements in Kozani

VI. FUTURE WORK

In the future we intend to manufacture more smart bins and deploy them formally with the approval city stakeholders in various urban and remote areas of our region to evaluate the effectiveness of our research

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