Riemann Garbage Bin: A Self-sustained Waste Management System

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Riemann Garbage Bin: A Self-sustained Waste Management System

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Abstract: This paper elaborates the idea for building a self-sustained sensor system, a network composed of nodes implementing the Riemann Garbage Bin (RGB) model. Hence, the case study explores the potential of employing sensor enabled systems to improve on waste monitoring and management in public waste bins. The network consists of wireless nodes that use ultrasonic sensors to measure the empty space in the bins. The sensors periodically report the fill rate of the waste bins to a sensor gateway that is based on Long Rage Wide Area Network (LoRaWAN) protocol. For our LoRaWAN server and network cover we choose to use The Things Network (TTN). These fill rates would be monitored by a mobile or web application connected to the network server. The goal of this project is through the Internet of Things (IoT) to monitor all the waste bins in one city, to improve the garbage management by relocating resources and by giving insight to the public about this global health threating problem.

Keywords – sensors, LoRaWAN, TTN, IoT

I. Introduction

During the last century the world population has been rising, and there has been a major migration from rural to urban areas. Today 50% of the world's population inhabit cities and this number is expected to reach 70% by 2050 [1]. As this global problem of migration shift towards the urban areas, the capital of the Republic of N. Macedonia, Skopje, also faces these complex problems like pollution, traffic and waste management. In parallel, the recent years have witnessed the rise of the 'smart cities', where the governments are challenged [2, 3] to tackle this health threatening problems with technology driven solutions. According to the Public Company Communal Hygiene Skopje the number routes for waste collection in 2018 has dropped for 2% in comparison to 2017 statistics. Hence, the amount of fuel used should also drop. But this is not the case. Fuel consumption int 2018 has raised for 3,3%. This number indicates that the trucks that collect waste are only suffocating the traffic flow and are causing more damage to the environment. Traditionally, waste collection has been preformed on a fixed schedule, which is the case in Skopje. However, regular schedule is not optimal as it does not account that different areas fill up their bins in different rates. This means collection trucks must stop at each point on their route to empty waste bin regardless of whether they are full or not. It also leads to situations where some waste bins overflow before the next collection schedule. Through our model we intend to provide a solution that would reduce the operational costs by streamlining their routes to deploying waste bins only where it is necessary.

II. Model Description

The RGB model is consisted of multiple components:

A. *Microcontroller*

The market for microcontrollers grew almost 10% from 2017 to 2018 [4]. This fast growth has made the Arduino microcontrollers and all sorts of different sensors highly available. Anyone with a simple idea and few dollars on their credit cards, can go online to Amazon or AliExpress and order these small devices. Although this availability and simple structure makes them easy to integrate in any IoT solutions, they hardly find direct usage in the industrial sector. Our solution focuses on building a low-cost IoT waste management system. Furthermore, Figure 1 shows the microcontroller that we use for controlling our sensors [5]. It is the Arduino Mega2560 board, by ELEGOO A high-performance 8-bit AVR RISC-based microcontroller combines 256KB ISP flash memory.

Fig. 1. Arduino Mega2560 Board [5]

B. *Opening system*

The constant unbearable smell cased by opened waste bins in Skopje has made us develop a certain type of opening system for bins that have lids. Although this solution is maybe inappropriate for implementing on bins that don't have lids, we made our protype model does have a lid. It uses one servo motor, which is triggered to open by the following three actions:

- RFID cards – these will be used employees from the Communal Hygiene
- Fire – if there is a fire detected the lid will open, making it easier for putting the fire out

- Pressure plate – when the plate is pressed it will open the lid for couple of seconds, allowing the person to throw waste

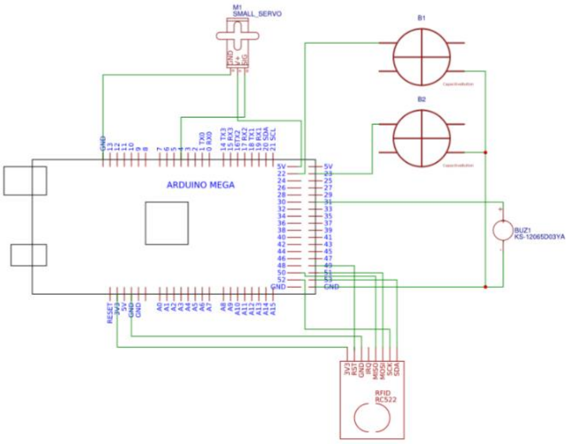

Fig. 2. Prototype opening system

C. *Fire detection system*

Being witnesses of many accidents of waste bins that are set on fire we put a flame sensor to detect ones. The data from this sensor is significant, hence it helps in reducing fires from spreading. This is done by sending information to the nearest firefighting unit about the location and the time where this fire has occurred.

D. *Volume measuring system*

For the volume measuring system we use ultra-sonic sensors attached to one servo motor.

1) *Rimeann sum*

We named our model after the famous German mathematician Georg Bernhard Riemann [6] who made many contributions to number theory and differential geometry. We came across his method for approximating the area under a curve using a finite sum. The sum is calculated by dividing a region into shapes (rectangular, trapezoids or parabolas) that form a region that is similar to the one being measured. By summing their areas, we

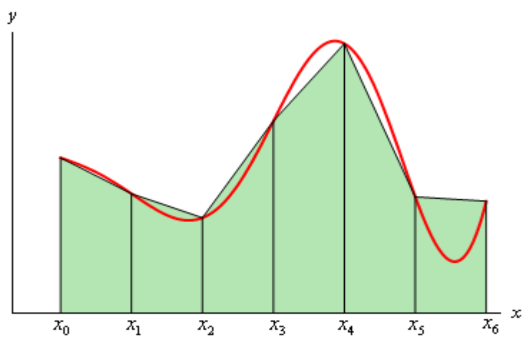

Fig. 3. Trapezoid Rule

approximate the region that is under the curve. Figure 3 show the Trapezoid Rule, that is a version of the Riemann method that uses trapezoids. We represent the empty space between the lid and the surface of the waste as the region that we want to calculate. Therefore, in real life the x-axis shown in Figure 3 would be the lid of the bin and the red curve the surface from the waste.

2) *Formula*

The points on the x-axis that are shown on Figure 3 are the ultra-sonic sensors that we use to measure the distance. Equitation (5) is the an example of how by using the distances measured from N ultra-sonic sensors (the $f(x_k)$ values for $k = 1,2,\dots N$) and the distances between the sensors (the Δx_k values for $k = 1,2,\dots,N$) we create trapezoids. By adding these trapezoids, we have calculated the approximated area from that region.

$$\sum_{k=1}^{N} \frac{f(x_{k-1}) + f(x_k)}{2} \Delta x_k = \frac{\Delta x}{2}\left(f(x_0) + 2f(x_1) + \cdots + f(x_n)\right) \qquad (7)$$

By placing these ultra-sonic sensors on a stick, attached to a servo motor, the approximation of the entire region has a new dimension. The servo rotates clockwise in different angles, allowing the sensors to calculate the regions in every rotation.

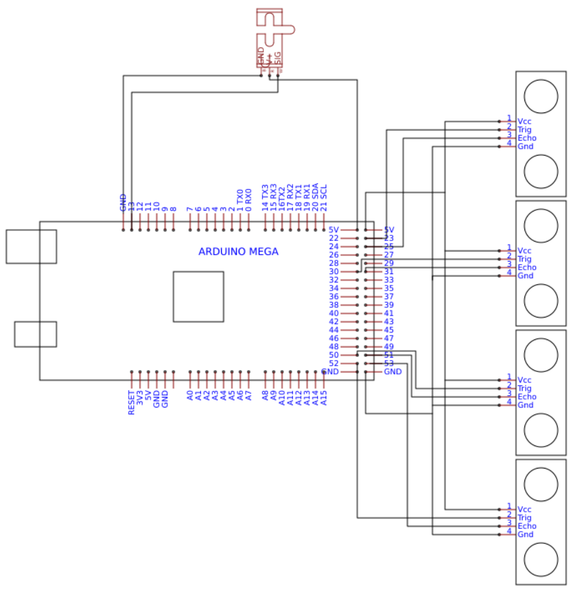

Fig.4. Prototype schematic for the measuring system

Figure 4 is a picture of how we resolved this issue. This way the system is covering more ground which leads to a better approximation. All the approximated areas are added together. Finally, in order to get the volume of this measuring we multiply this summed approximated area by rπ, where r is the radius of the lid (if the shape of the bin is cylinder which is our case study).

E. Data transfer

Sensor nodes are simple devices that can measure the empty space in trash bins using ultra-sonic sensors, and later transmit the data to the backend. Wireless communication is one of the key aspects of the design of the sensor node, and the overall topology of the system. Figure 5 represents the different technologies that are developed in the 21st century [8]. Some are likely to have high bandwidth (Wi-Fi), long range (GSM), high data rate (Cellular), low power (Bluetooth low energy (BLE)), or mesh-network capabilities (ZigBee). While all these technologies are considered to be mature, none of them are optimal for IoT projects. Generally, the problem is their power consumption. Higher data rate requires higher power.

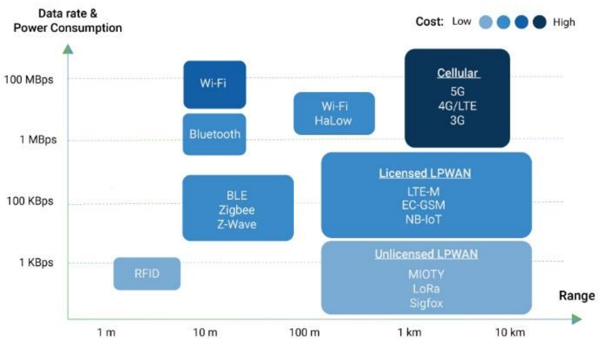

Fig. 5. Wireless technologies [8]

Whereas, the RGB model does not need to send pictures or videos it only needs report a percentage (the fill rate). That is why LoRa technology [9] is a perfect fit. This spread spectrum modulation technique derived from chirp spread spectrum (CSS) technology, which allows sending small messages on long ranges.

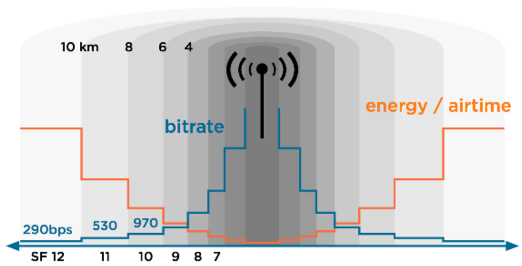

Fig. 6. LoRa spreading factor scalability [10]

The low data rate, uses less power, making this wireless platform the de facto technology for the IoT networks worldwide. Figure 6 shows the scalability of the spreading factor of this technology. As you can see smaller messages have higher airtime which means higher spreading factor [10].

F. LoRawan / The Things Network

LoRaWAN [11] is a media access control (MAC) protocol for wide area networks. It is designed to allow low-powered devices to communicate with internet-connected applications over long-range wireless connections. LoRaWAN can be mapped to the second and third layer of the OSI model. It is implemented on top of LoRa or FSK modulation in industrial, scientific and medical (ISM) radio bands. The LoRaWAN protocols are defined by the LoRa Alliance and formalized in the LoRaWAN specification.

LoRaWAN operates in unlicensed radio spectrum. This means that anyone can use the radio frequencies without having to pay million-dollar fees for transmission rights. It is similar to Wi-Fi, which uses the 2.4 GHz and 5 GHz ISM bands worldwide. The fact that LoRaWAN frequencies have longer range also comes with more restrictions that are often country-specific. In Europe, frequency band is in the 863-870 MHz frequency band. European frequency regulations impose specific duty-cycles on devices for each sub-band. These apply to each device that transmits on a certain frequency, so both gateways and devices have to respect these duty cycles.

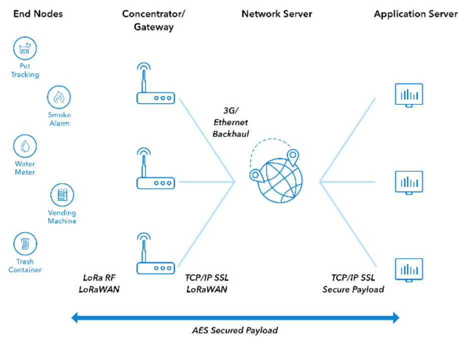

Fig.7. LoRaWAN architecture [12]

LoRaWAN architecture (Fig. 7) is also based around the use of nodes, gateways that – similar to Wi-Fi access points – pick up signals from the air and convert them, and a network server (an entire distributed infrastructure, in some cases) that effectively serves as data bridge to the application [12]. Figure 8 shows how the data transmitted by a node can be simultaneously picked up by multiple gateways, while encryption keys ensure that the network will accept the message and the application can process the decrypted data [13].

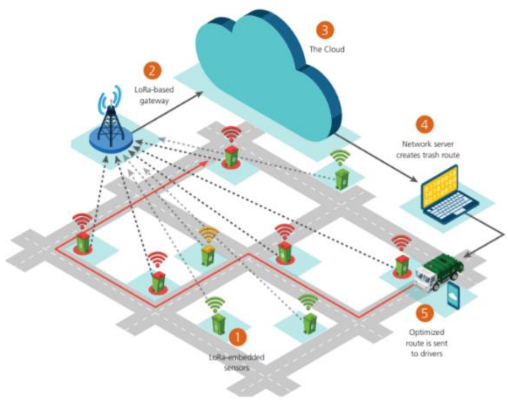

Fig. 8. LoRaWAN waste management system [13]

The Things Network [14] is a community-based initiative aimed at interlinking LoRaWAN gateways in order to create a large global network. The aim is to minimize the number of central components, while offering users the broadest possible range of options. Gateways can transmit data to multiple network servers, allowing for the creation of private networks and exchange data with TTN.

G. Backend

The backend consists of a cloud-based app that receives data from the nodes using MQTT (Message Queue Telemetry Transport) protocol [15]. MQTT is light weighted and requires limited network bandwidth, making it optimal for such short messages. The data is stored in a database which allows flexibility to test out what data might be useful to send a store without major changes. This also allows the implementation of the solution into any existing management systems.

Fig. 9. Prototype

III. Conclusion

Making cities cleaner is provided with the idea of implementing a LoRaWAN waste management system of nodes. Waste management has become a reality rather than a problem. This case study based on placing sensors embedded with LoRa on existing waste bins, and through periodical reports of their fill rates, has shown that we can monitor fill level and reduce operational costs. As a result, this project through the IoT will improve the garbage management by relocating resources and by giving insight to the public about this global environmental problem.

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