A dynamic real time scheduling algorithm for optimum garbage collection in a city using IoT smart bins.

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INTRODUCTION

According to the 2018 Revision of World Urbanization Prospects produced by the Population Division of the UN Department of Economic and Social Affairs (UN DESA) almost 55% of the world's population lives in urban areas and the prediction is expected to be 68% by 2050. One of the crucial matters that the modern cities have to face 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. This situation of overflowed garbage bins in public places creates an unhygienic atmosphere and it may induce numerous diseases both in humans and animals. The generation levels of urban solid waste in Municipals, as stated by the World Bank's review report [1], in 2012, were around 1.3 billion tons per year and it is expected to reach 2.2 billion tons per year by 2025. 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]. Furthermore, according to [3] 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 [4].

Using the Internet of Things (IoT) with a dynamic scheduling and routing can reduce the collection and disposal cost up to 20% and the transport distance to 26% [5]. 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.

Current waste management trends are not sophisticated enough to achieve a robust and efficient waste management mechanism. For avoiding these negative effects, the garbage bins and the garbage management system must be improved by utilizing Internet of Things (IoT). In this research, we propose an "e-smart bin management system" based on an innovative algorithm developed by our team. Our system consists of three parts a) the hardware, b) the software and c) the communication. We are using a microcontroller Arduino Uno and ultrasonic sensors, to measure the volume of garbage. The collected information is stored temporarily in microcontroller's RAM and sends it via the LoRa (Long Range) protocol to the Information System (IS) where the users can monitor each bin and be notified for emergency incidents.

RELATED WORK

Hitesh et al. [6] proposed an e-smart bin which takes measurements of the bin such as the fulfill percentage and the temperature. After that, using a Wi-Fi shield, measurements are sent to the information system where the user can view and use the data.

Bashir et al. [7] proposed a model where providers will have the option to track weight and identity of each garbage bin. By using the Global System for Mobile communication (GSM) technology sends a notification alert to an authorized garbage truck when the bin is almost full. Even though the methodology proposed by the authors [6] [7] is well documented, it is lacking the implementation of an intelligent system that predicts and dynamically adjusts garbage collection paths for the garbage trucks.

Our work differs from the aforementioned ones in two key points: (a) we propose a Smart Bin architecture that fully implements the core ideas of IoT (low power consumption, small form factor, inexpensive to manufacture) and is capable of operating in a radius of up to 27km due to the LoRa technology. Moreover, the proposed system (b) fully implements an IS that can be used by system administrators to supervise the status of all bins and dynamically adjust the daily paths for the garbage collection trucks, resulting in less fuel consumption and wasted time.

THE PROPOSED SYSTEM

The proposed system consists of two main components: (a) embedded system inside the smart bin (Figure 1) and (b) Information System (IS) aggregator and backend processing.

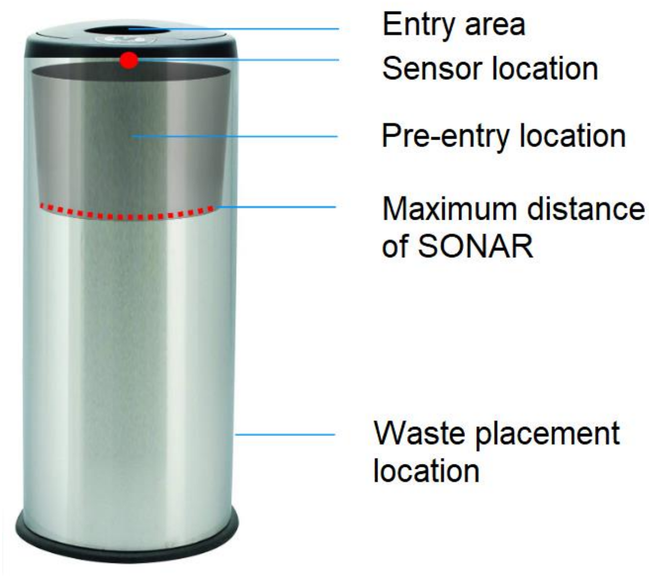

Fig. 1. Smart Bin prototype

A. Embedded system inside the smart bin

Each smart bin is equipped with multiple low power consumption sensors, such as ultrasonic, humidity and temperature sensors. Every time the bin is opened, the installed Arduino on the smart bin captures measurements from all sensors. Using the LoRa actuator on the bin, these measurements are sent to the LoRa gateway installed on the IS. One of the innovations our system offers is the phase continuity insurance between different chirp symbols in the preamble part of the physical layer packet, which enables a simpler and more accurate timing and frequency synchronization, without requiring expensive components for generating a stable local clock in the LoRa node. The microcontroller, sensors and circuits installed on each smart bin are specifically chosen and designed to minimize power consumption and allow operation of many weeks before the need to recharge.

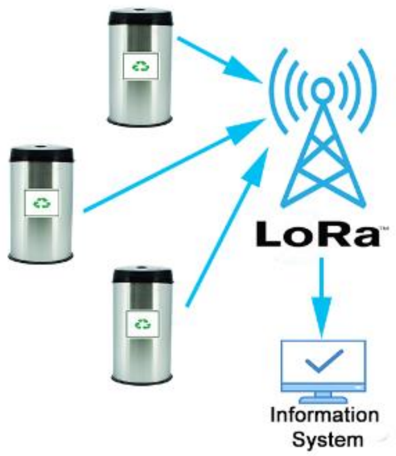

Fig. 2. LoRa connection between the smart bins and the Information System

B. Information System aggregator and backend processing

Using the LoRa gateway, data is being collected from the Smart Bins and processed by the IS. At any point in time, users and administrators can view information and the status from all the Smart Bins installed in the city. This information includes but is not limited to: fullness percentage, when the lid is open, current and past temperature and humidity measurements. The main innovation of the IS comes from the Artificial Intelligence (AI) algorithms implemented. Using historical and current measurements from each smart bin, our algorithm can predict with great accuracy when each smart bin will be completely full. The final innovation of our system comes from the waste collection dynamic scheduling. By knowing which bins are close to full capacity and which bins are empty, an intelligent system based on Dijkstra’s algorithm [8] and Spanning Tree Coverage [9] calculates the path that the garbage truck will follow [10]. The system utilizes weighted graphs and emphasizes on minimizing the total drive distance while maximizing garbage collection from the smart bins. The core idea of the route planning system is that bins which are almost empty are completely skipped by the garbage collection truck. As a result, fuel consumption and time wasted is minimized by a large margin.

C. COMMUNICATION

Another major difference from other systems is the connection between the bins and the main platform. In our work, we use LoRa. LoRa is a proprietary spread spectrum modulation technique by Sentech and can be used with any MAC layer. LoRaWAN is the proposed MAC which operates. 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 and •LoRa NetServer: the network server that controls thew hole 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 synchronization, without requiring expensive components for generating a stable local clock in the LoRa node.

D. GARBAGE COLLECTION PROCESS

Before the garbage collection takes place, The municipality employee who is driving the garbage collection truck uses the Information System to find which are the full bins and which are the empty ones. The Information System provides information regarding all the smart bins within the city. The driver of the garbage collection truck can set a threshold, specifying which levels of fullness are accepted. For example, if many smart bins are currently 100% full, the driver can decide to only pick up these smart bins and leave the 20% for the next day. This way, no energy is wasted driving for a smart bin that is only half empty, or completely empty.

Another great feature of the smart bin Information System is the waste prediction mechanism. This mechanism detects the daily activity of the bins; it calculates the daily waste fullness percentage, and can predict when a smart bin will be full of waste. If for example a smart bin increases its fullness by 5% each day, the system can predict that if it is currently at 70%, it will need 6 days for the bin to be full. The Information System can notify the driver few days earlier so that the bin will be emptied before overflowing of garbage.

EXPERIMENTAL RESULTS

In order to evaluate our system, we installed several Smart-Bin devices in several homes in the city of Kozani. We conducted multiple experiments from 25th of June to 25th of November within the city of Kozani. Fig. 3 shows some of the locations of the homes in which we tested the IoT Smart-Bin devices. The data transmission rate of the LoRa modules proved to be more than enough to to transmit the required data in a timely manner to the server. Results suggest that the proposed system architecture, utilizing the power of cloud is feasible in small and large scales.

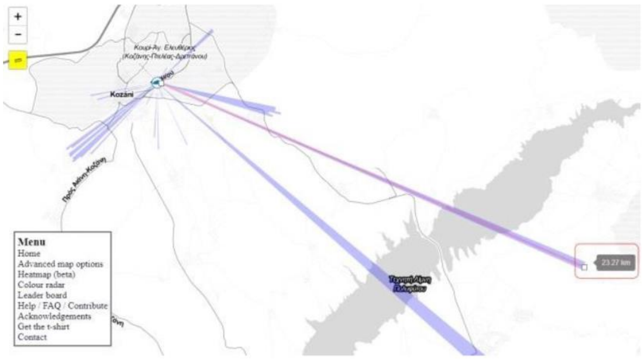

Fig 3. LoRa and its maximum supported distance of 27 km. The LoRa gateway located in the city of Kozani can server smart bins located in nearby villages.

FUTURE WORK

Our future work is to improve the recycle smart bin by installing a belt mechanism where the waste items fall into it and separates them based on material in different internal bins. Also, we are improving the system of the smart bin for urban garbage to optimize the routing of the garbage trucks. Finally, we are researching for a new smart bin where the citizens could place the wasted food and they will gain points. This will solve another big problem of wasting food by making the compost process popular.

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