Engineering

DEVELOPING AND IMPLEMENTING SOFTWARE SOLUTIONS TO INTEGRATE WASTE COLLECTING SYSTEMS INTO SMART CITY INFRASTRUCTURES

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ABSTRACT:
A COMPLETE INTEGRATION OF WASTE COLLECTING SYSTEMS INTO SMART CITY INFRASTRUCTURES IS MANDATORY FOR A CITY TO BECOME TRULY "SMART". BY USING A SMART WASTE MANAGEMENT SYSTEM, COMPANIES, AUTHORITIES AND POPULATION CAN MONITOR AND MANAGE THE WASTE FLOWS IN THEIR CITY. IN THIS PAPER, SOME PRELIMINARY RESEARCH RESULTS REGARDING A SOFTWARE DEVELOPMENT AND IMPLEMENTATION FOR INTEGRATING WASTE COLLECTING SYSTEMS INTO SMART CITY INFRASTRUCTURES ARE PRESENTED. THE DEVELOPED PLATFORM CONSISTS IN A GPS/GPRS MODULE AND ULTRASONIC SENSORS CONNECTED TO A ARDUINO BOARD. THE SOFTWARE APPLICATION ALLOWS TO SEND SMS INFORMATION ON REQUEST, PROVIDING CONTAINERS FILL LEVEL AND GPS COORDINATES TO PROPER PLAN THE TRANSPORT OF CONTAINERS WITH WASTES FROM THE COLLECTING SYSTEM TO THE RECYCLING PLANTS.

KEY WORDS: SMART CITY, WASTE MANAGEMENT, GPS/GPRS MODULE, IoT

INTRODUCTION

Currently, most urban waste collection operations are accomplished by emptying containers according to predefined programs. This is inevitably ineffective, with the emptying of half the containers, the inappropriate use of the city's assets and the unnecessary fuel use of the fleet[5]. Innovative waste management systems are essential to the success of smart cities where it is necessary to create a community that benefits economically from being "smart" about its resources[6]. The proliferation of sensors and actuators enable the new

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[5] Christina Jung; IoT and Smart City trends boost smart waste collection market, https://www.greenbiz.com/article/iot-and-smart-city-trends-boost-smart-waste-collection-market, 2017
[6] Robin Bisarya; How Smart Green Cities Turn Waste into a Resource, http://www.regreenus.com/uploads/smart-green-cities-ft-zeons.pdf, 2016

era of Internet of Things (IoT) that can be adopted in Smart Cities and help in Waste Management[7].

Several solutions can be found in specialized literature, for example Ludin et al. propose a system of wireless nodes that use ultrasonic sensors to measure the empty space in the bins, a sensor gateway that is based on Long Rage Wide Area Network (LoRaWAN) protocol and cloud-based back/front end for data collection, analysis and visualization[8]. Their case study was based on only 6 bins.

The research conducted by Anagnostopoulos et. al. focused on a Smart City where a number of collection bins are located in different areas with sensors attached to them. They described how the system effectively responds to the demand as realized by sensor observations and alerts originated in high priority areas. The aim was to minimize the time required for serving high priority areas while keeping the average expected performance at high level[9].

Shyamala et al. propose a smarter way of conventional waste management using smart sensors to gather fill-level data, presence of garbage around the dustbin and send it to servers in real time by using communicating modules (GSM/GPRS module), the entire operation is controlled using a Atmega328P 8-bit microcontroller[10].

Our proposed solution is dedicated for an integrated separate waste collection system where plastic recipients, aluminum cans, bottle recipients, small and large appliances, paper and carboard are collected. In this way, several separate waste collection systems can be monitored in real time and proper transportation route to the recycling plants can be planned.

IoT PLATFORM SOLUTION

We developed an IoT solution which supervises the filling level of the containers from the separate waste collection systems and sends this information remotely. There are two models of implementation. The first model includes an GPS/GPRS module which sends the information by SMS and second model is a web based solution that can send the information live using a socket connection to a central server.

Model one

We chose an Arduino development board as IoT controller and a GPS/GPRS shield. As a waste level sensor, we used an Ultrasonic Module Hc-Sr04 Distance Measuring Transducer Sensor for Arduino. The components needed for this implementation are:

- 1 x Arduino
- 1 x Ultrasonic Module Hc-Sr04 Distance Measuring Transducer Sensor (figure 1.)
- 1 x GPRS+GPS Quadband Module for Arduino (SIM908) (figure 2.)
- 1 x GPRS antenna
- 1 x GPS antenna
- 1 x SIM card

[7] Theodoros Anagnostopoulos et al.; Assessing dynamic models for high priority waste collection in smart cities, Journal of Systems and Software, 2015

[8] Andre Castro Lundin et al.; Smart cities: A case study in waste monitoring and management, Proceedings of the 50th Hawaii International Conference on System Sciences, 2017

[9] Theodoros Anagnostopoulos et al.; Assessing dynamic models for high priority waste collection in smart cities, Journal of Systems and Software, 2015

[10] Shyamala S.C et al.; Smart waste management system, International Journal of Scientific Development and Research, 2016

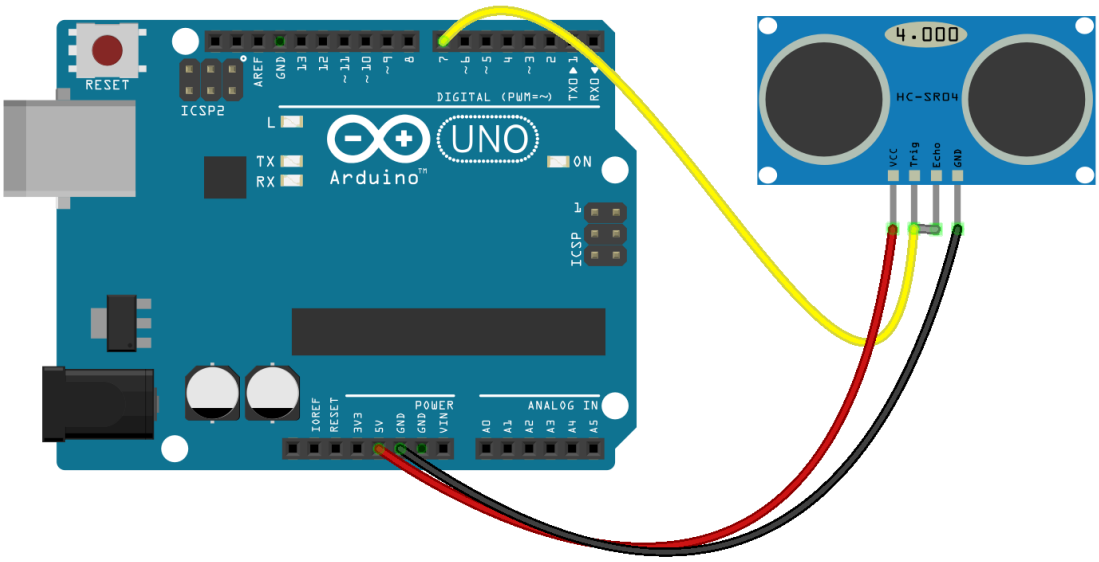

Figure 1 Hc-Sr04 sensor wired to the Arduino Board

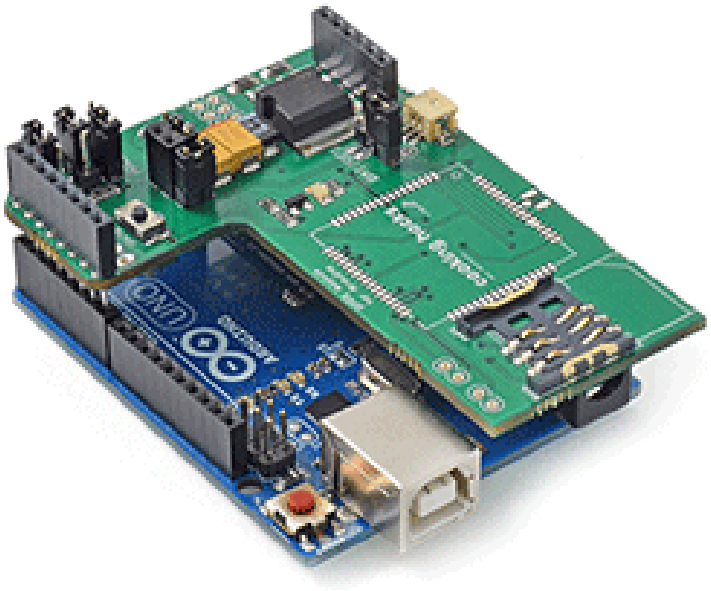

Figure 2 GPS/GPRS shield connected to Arduino[11]

The Ultrasonic sensor mounted on the top of the container continuously measures the level of the waste in the container. When a user calls the number of the SIM card inserted in the GPRS module, the system replies by a SMS containing the level of the waste and the GPS position. This implementation is designed for isolated and mobile containers, placed in different zones of the city.

Model two.

For this model, we use also the Ultrasonic sensor connected to Arduino development board, and for communication we used Johny Five IoT java script platform[12] and node.js[13].

[11] Arduino; https://www.arduino.cc/

This implementation is designed for multiple containers collocated in the same zone (for selective waste collection system). Each container has a sensor and an Arduino board. A local edge micro server, reads the level of each container and stores the data in a local database based on container ID. The edge micro server can be remotely interrogated by a central server and can send programmatically alert messages by SMS or email.
The components needed for this implementation are:

- n x Arduino
- n x Ultrasonic Module Hc-Sr04 Distance Measuring Transducer Sensor
- 1 x Dual Core 1Ghz ARM-A9 Linux Server with Wifi Thin Client
- Wifi / wired internet connection, or 3G/4G modem

Where n is the number of waste containers colocated in the same location and interogated by a single edge server.

All Arduino boards are connected to the micro server by an USB Hub, and have a different virtual communication port mapped on the JohnyFive.

The server read data from each mapped virtual port and store the information (container ID, time stamp, filling percent) in the local database. When a central srever send a read request by socket.io, the latest data storred are transmitted in json format.

Also, when some containers reach the maximum filling percent, the server send to a preconfigured list of emails and phone numbers, allerts by emails and /or SMS.

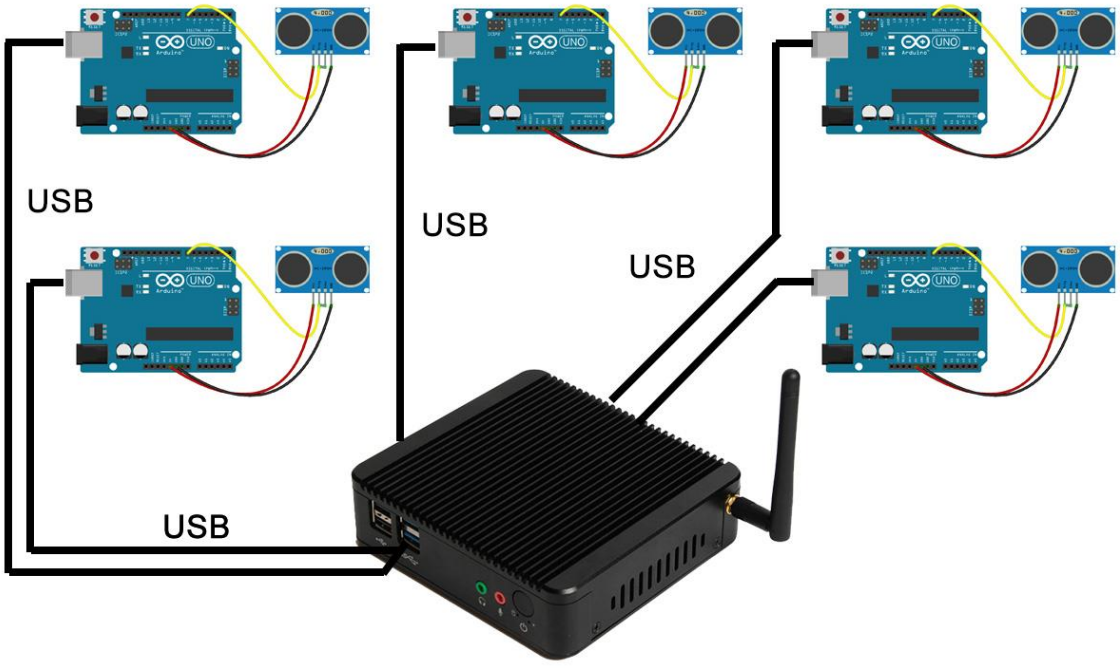

Figure 3. Connection diagram

The micro server has a web interface where all the information regarding the level of each container, and waste type is displayed.

The central server application (based on PHP and MySQL) can read on timed interval (CRON based) the data from mobile containers and from collocated containers and display

[12] Johny Five JavaScript Robotics & IoT Platform http://johnny-five.io/
[13] Node.js https://nodejs.org/en/

the information on a map. Also, the application can provide the most economical route to unload the containers.

The central server has a GPRS module and when the CRON commands are triggered the application reads from the database the phone numbers of mobile containers and calls them sequentially. After the call routine, the central server will receive by SMS the required information and process them to be stored in the database.

To interrogate the micro edge servers the socket protocol can be used and data will be retrieved and stored in real time.

The data sended by SMS and by socket connection contain: container ID, time stamp of the reading (Unix time in seconds), latitude and longitude of the container location, filling state (in percent).

All the data received by SMS and by socket connection are storred in a history database, based on time stamp, and the most recent ones will be retreived from database and showed on the server web interface on a map representation. The web interface is based on leaflet .js[14], the leading open-source JavaScript library for mobile-friendly interactive maps, Leaflet Routing Machine[15] and Open Street Map[16].

To display the data and route on the map the leflet routing machine will be initialised with an array of:

- container ID (numeric)
- latitudes, longitudes (in grades and minutes),
- pointMarkerStyle - color of the point based on container filling percentage: green: 0-50%, orange 51-90%, and red 91-100%
- container content (paper, glass, weee, pet etc).

Based on this array the optimal route wil be drawed on the map.

[14] The leading open-source JavaScript library for mobile-friendly interactive maps. https://github.com/Leaflet/Leaflet

[15] Control for routing in Leaflet; https://github.com/perliedman/leaflet-routing-machine

[16] Open Street Map Project; https://www.openstreetmap.org

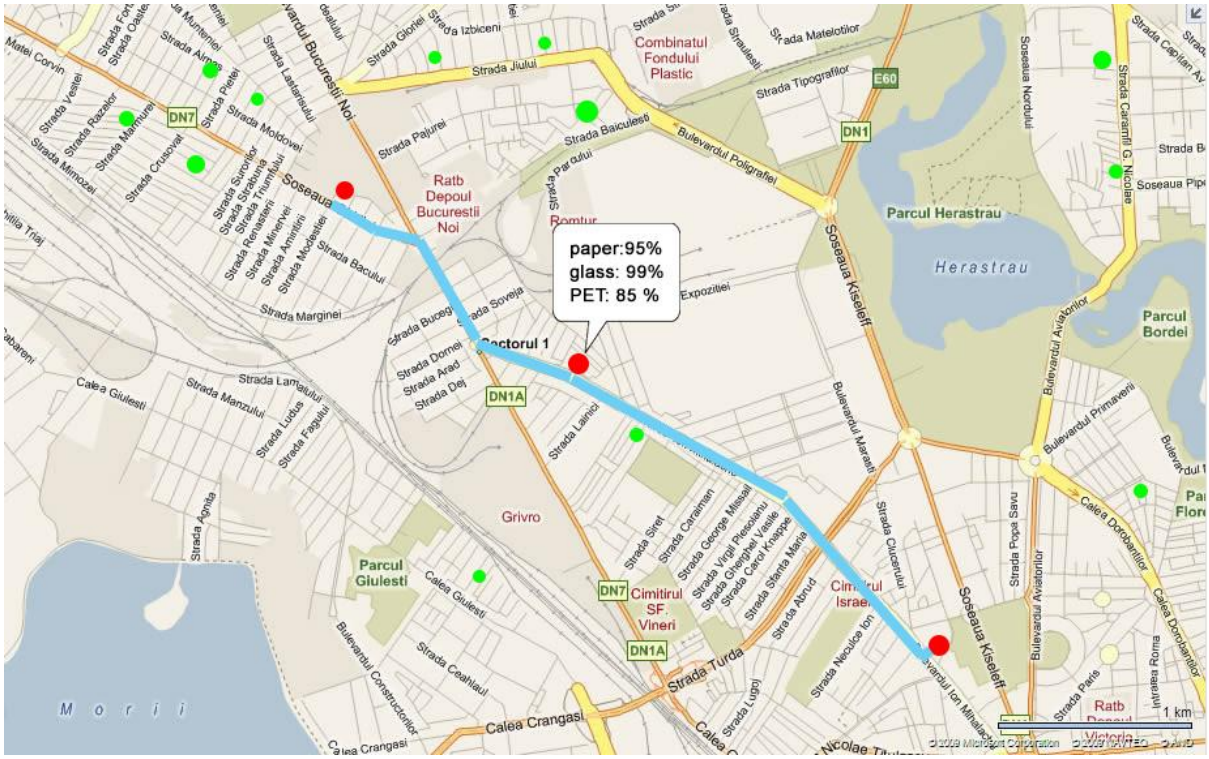

Figure 4. Web Based map interface on central server

CONCLUSION

Our proposed solution is able to gather information from multiple containers collocated in the same selective waste collection system. Containers with different types of waste (plastic recipients, aluminum cans, bottle recipients, paper and carboard etc.) can be monitored in real time.

Also, other information from the selective waste collection system can be provided for companies, authorities and population, for example: equipment status (working, blocked, needs repairs or maintenance etc.), storage system status (allows full reports for all waste types), the total amount of wastes collected allowing optimal discharging, route optimization for waste discharging (on city or county level).

Our future research will be focused on implementing the LoRaWAN™ technology in our proposed platform.

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11. **Control for routing in Leaflet**; https://github.com/perliedman/leaflet-routing-machine
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