Development of Low-Cost Wireless Sensor Network for Solid Waste Management

Goran Mateski[1], Ramona Markoska[1], and Aleksandar Markoski[1]

[1] Faculty of information and communication technologies, Partizanska bb, 7000 Bitola, Macedonia
goran.mate@yahoo.com, ramona.markoska@fikt.edu.mk, aleksandar.markoski@fikt.edu.mk

Abstract. Waste generation is one of the major problems in modern societies, not only for the quantitative of waste generated, but also for the increasing complexity of process of waste collection. Main objective of the different methods for collecting the waste routing optimization to minimize the total route cost. Algorithms which are solving Vehicle Routing Problem depends on real-time data which can be provided only by ad sensors. A low-cost sensor node and sensor network for waste detection are developed and presented in this paper. Sensor node is based on ultrasound sensor and Arduino open-source hardware and software. Measured data are collected and stored in Thing Speak cloud server, and they can be used for visualization, analysis, and as input for algorithms solving Waste Collection Vehicle Routing Problem.

Keywords: solid waste detection, ultrasonic, sensor network.

1. Introduction

Solid Waste Management is one of the most complex problems in modern societies, not only for the quantitative rise of the amount of waste generated, but also for the increasing complexity of some products and components. Waste collection is a very complex logistics operation, and how to collect waste in an efficient way is an area that needs to be improved.

Solid Waste Management System architecture is presented on Fig. 1. Components of the system are: waste sensors, RFID tags, communication modules, GPS units, database servers, software for integration and visualization of all collected data, and finally software which solves the most important problem: routing optimization to minimize the total route cost. This problem in literature [1] is defined as Waste Collection Vehicle Routing Problem - WCVRP.

According to [2] identification of a route for Municipality Solid Waste collection trucks is critical because from the total amount of money spent for collection, transportation and disposal of solid waste, approximately 60–80% is spent on the collection phase. Significant savings of money, fuel and time can be obtained using the combination of modern technologies providing the necessary data (sensor network, databases) and algorithms for intelligent routing (Fig. 2).

Fig. 1. Architecture of the Solid Waste Management System

In addition, by lowering the number of collections the noise of garbage trucks will be decreased significantly and the emission from trucks in the atmosphere will be lowered because the fuel consumption will decrease.

Fig. 2. Static vs Intelligent routes based on Sensor data

The main component of the Solid Waste Management System is a sensor node capable to identify the level of the waste of so called “smart bin” shown on Fig. 3.

Fig. 3. Concept of "smart bin" with installed ultrasonic sensor

In the literature, many methods and principles of waste detection have been used [3], [4], [5]. Also there are several commercial solutions at the market. Availability and very low price of the electronics, controllers, sensors, and communication modules based on Arduino open-source hardware, gives us opportunity to develop a low-cost sensor nodes and sensor network which will be used to provide necessary data for development of algorithms and software for WCVR Problem solving.

2. Development of Sensor Node

The main component of the system is ultrasonic module HC-SR04 used for non-contact measuring from 2cm up to 400cm with 3mm precision. It consists of ultrasonic transmitter, receiver and circuit. The function is based on sharing 8 signals of 40 KHz and checking if there is a returning pulse. After that if we have returning pulse while the I/O port is opened, we get the period from sending until receiving of the signal (Fig. 4).

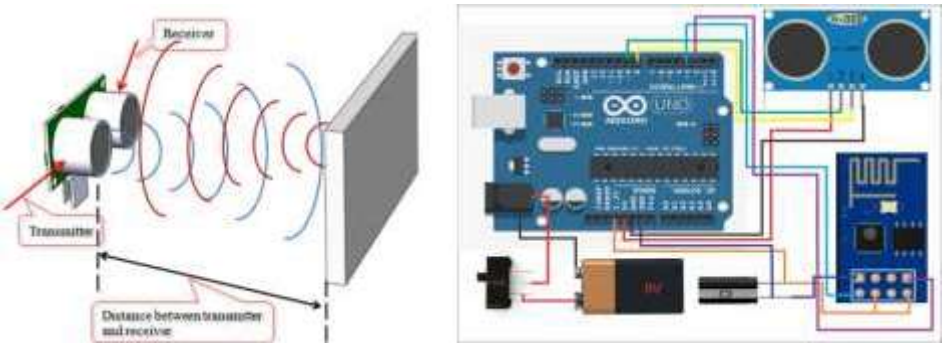

Fig. 4. Principle of measurement and components of the sensor node

The sensor node uses microcontroller Arduino Uno based on AT Mega 3328, ultrasonic sensor type HS-SR04, module for wireless communication WIFI ESP8266, battery 9V, capacitor 2200 μF and slider switcher with two conditions. (Fig. 4).

ESP8266 is used for wireless networking, and enables usage of applications or transfer all of the wireless network functions onto application space. Its usefulness is proven by the amount of data that it can process and collect. This system include fast reaction, adaptable radio waves while low expenses, processing the signal in advance and capability for networking with other technologies. Main element in the sensor node is the microcontroller, Arduino Uno onto which are connected other elements. The ultrasonic sensor HC-SR04 includes 4 pins from which, 2 pins are used for powering and 2 of them are used for communication with the I/O ports of the microcontroller.

Working principle is based on 5V voltage which enables direct connection with Vcc pin and the pin for powering from 5V out of microcontroller. Grounding pin (GND) is connected to one of the two pins from the microcontroller. The rest of the pins from the ultrasonic sensor are connected to the I/O digital ports of the microcontroller, with consideration of the programming code. While wireless module for communication is into working mode, it uses higher level of powering, around 50mA which may cause the module to be prevented from function. In order to avoid such a situation, capacitor from 2200μF is used. Pins for powering (Ch_PD) and (+3v3) from the module, are connected to the positive pin from the capacitor while pin GND is connected to the pin for powering from 3.3V of the microcontroller, the same goes with the negative pin of the capacitor.

In order to establish wireless communication, microcontroller uses two pins, Rx and Tx, with the usage of different locations of connection while programming and connecting. Powering the node is established by battery from 9V which includes two contacts (positive and negative). For changing state of work, slider switch is used in two states and 3 pins for connection. All elements are packed in practical box, which must be easy for packing and unpacking so that whenever there is an element out of function, it could be replaced immediately. In order to be programmed and configured, the microcontroller together with additional elements, uses the software Arduino IDE 1.6.7 version.

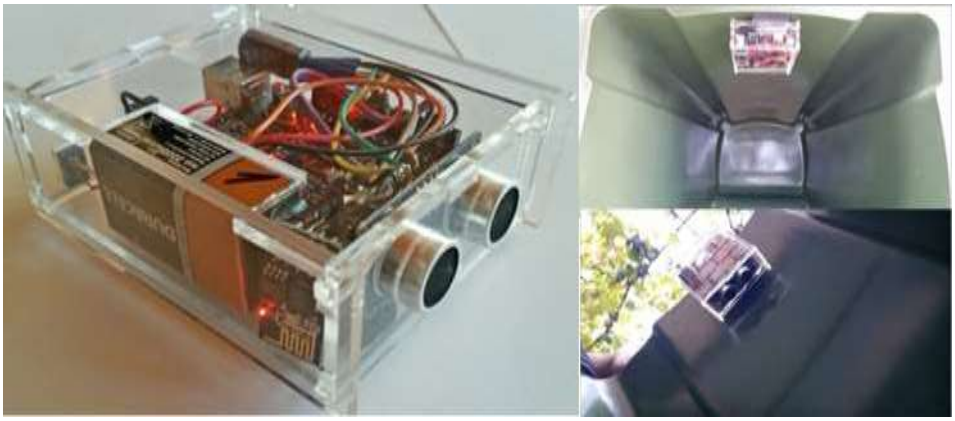

Fig. 5. Complete Sensor Node and placement in “smart” bin

Based on the ultrasonic sensor principle of work, the node is positioned near to the top edge of the garbage container. Ultrasonic sensor does the measuring with sending radio wave which is declined of some obstacle inside the container and is turned back to

the receiver. In the following way, the calculation of speed, time and density, determines the value of the garbage which is contained into the container.

The process starts with turning ON the switcher on the node, after that follows the process of measuring the distance from ultrasonic sensor until the bottom of the container. When turned on, the container should be empty in order to record the maximum distance (calculating the space between the minimum and maximum level in the garbage container). When the distance is recorded, the controller is activating the module for wireless communication who is sending information to the repeater. When connected to the router, measured data is sent and the connection is interrupted. If the router is not available, the process is repeated until the connection is not established.

According to the program, the time interval of measuring and sending data to the repeater can be lower than 5 seconds and it is repeated without interruption. Server is available to display eight of the sensors data in eight fields adapted for that data. With declaration of the address in program, data is displayed on the particular field from channel on the server in every 15 seconds. In real application time interval should be much bigger, in order of several minutes, which will lower power consumption and it will increase battery life.

3. Architecture of the system

Because main aspect of the node development is providing data for development of the algorithms and software for WCVRP, we used very simple network architecture for connecting the sensor nodes to the system using Wi-Fi connection with ESP8266 shown on Fig. 6. Instead of building complete server and database solution, measured data are sent to ThingSpeak cloud (https://thingspeak.com/).

Fig. 6. Integrated System for Waste Management and Control

The ThingSpeek server has capability to collect data at real time, visualize it in collected form out of the data table, produce plugins and applications for using web-

services, social networks and other platforms. ThingSpeak enables usage of a big variety of different visualization types and activities that may be inputted in the page with graphs by special plugins. There are two types of plugins, ones are for visualization and analytics and another ones are based on activities. Analytical data is used for precise visualization based on the type of the data. The activity plugins are used for control and representation of changing activities.

In order to be used, it is obligatory to have profile and log into the official page www.thingspeak.com where the channel will be created. With registering on the channel, the API code is also created as unique for that profile. The profile could contain more channels and the data could be represented either public or private (only for the user). API codes are used while programming microcontrollers and its components. There are two API codes, API code for writing is automatically generated by the channel, opposite to the API code for reading which must be generated by the user. In that way the communication is established and the data may be transferred.

4. Testing of the System

In order to test the system three Sensor Nodes are deployed on the city of Ohrid, Macedonia, on location shown on Fig. 7., with measured data and graphs from ThingSpeek are shown on Fig. 8.

According to our experience, there are a lot of places where you can position the wireless sensor node, but the best place according to our research is on the top of the container. This principle of working has many disadvantages. Basically the container may be left opened sometimes because of inattention which may result in inaccurate results, also vandalism which is often present in the streets may cause problems from different kinds with the node inside. But there is a solution for these problems too, like positioning sensors for heat, vibrations etc. They may register and send these data to particular
like police or fire station in order to report vandalism or waste burning.

Fig. 7. Locations of tested "Smart" bins

For more precise display and review of the data in the system for control and maintenance of the garbage, Google plug-in is used, which displays measured data in

form of gauge in different colors (Fig. 9.) which shows the current level of waste in the bin. The colors are adapted to the level of garbage in the container

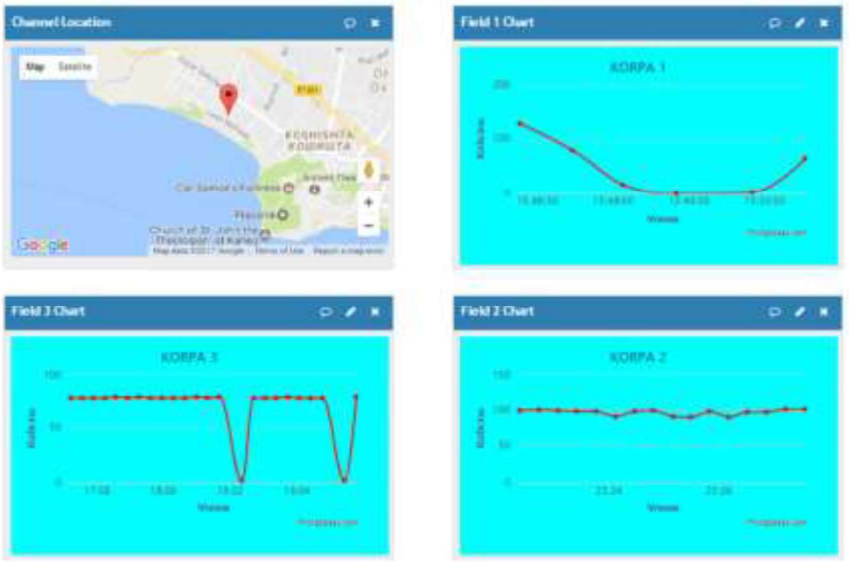

Fig. 8. Graphs from measured data on ThingSpeek

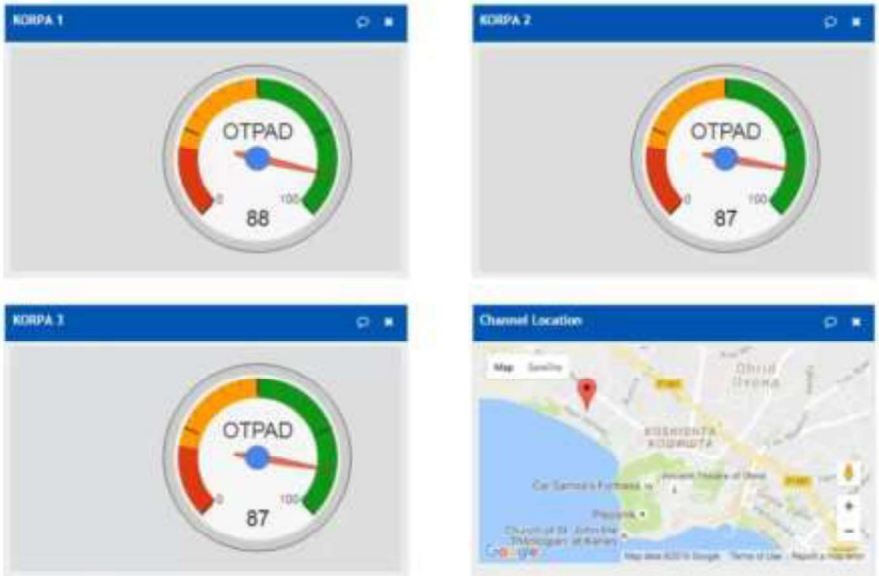

Fig. 9. Current waste level

ThingSpeak Server is capable to collected 8000 measurements on single channel and that data can be saved in form of CSV format. It allows data to be inputted into the software for analysis and collecting data for further processing in WCVRP modelling.

If it is necessary, sensor node can be updated with additional sensors and modules in order to be capable to send and receive more data and perform more precise measuring. In order to enable the node to perform activities outside the community where wireless networks are not available, system could be adapted to communicate by GSM/GPRS module which may perform the same function on wider area. For longer performance of the battery, life of the battery may be prolonged using solar charging or batteries with bigger capacity.

5. Conclusions

This paper focusses on development of low-cost wireless sensor network for solid waste management. Complete solution based on Arduino open source hardware, sensors and communication modules is presented. The solution is simple, can be realized with minimum investment per sensor node, but still effective for various applications. In this version, all data are stored in ThinSpeak cloud which can be also used for analyses and visualization. System was tested on-field and first result shows that this concept can be improved and widely used not just for research purposes, but also in real practical applications as a part of the Solid Waste Management System.

References

1. H. Han, E. Ponce-Cueto: Waste Collection Vehicle Routing Problem: Literature Review, Promet – Traffic&Transportation, Vol. 27, No. 4, 345-358, (2015).
2. Karadimas N.V., Papatzelou K., Loumos V.G. Genetic Algorithms for Municipal Solid Waste Collection and Routing Optimization. In: Boukis C., Pnevmatikakis A., Polymenakos L. (eds) Artificial Intelligence and Innovations 2007: from Theory to Applications. AIAI 2007. IFIP The International Federation for Information Processing, vol 247. Springer, Boston, MA, (2007).
3. Md. Abdulla Al Mamun, M. A. Hannan , Aini Hussain , Hassan Basri, Wireless Sensor Network Prototype for Solid Waste Bin Monitoring with Energy Efficient Sensing Algorithm, Proceedings of the 2013 IEEE 16th International Conference on Computational Science and Engineering, p.382-387, December 03-05, (2013).
4. S. Longhi et al., Solid Waste Management Architecture Using Wireless Sensor Network Technology, in 5th International Conference on New Technologies, Mobility and Security (NTMS), pp. 1-5, (2012).
5. V.Catania, D.Ventura, An approch for monitoring and smart planning of urban solid waste management using smart-M3 platform, 15th Conference of Open Innovations Association FRUCT and 3rd Regional Seminar on e-Tourism, (2014).