IoT-Enabled Citizen Attractive Waste Management System

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Abstract— Current cities worldwide have a goal to be smarter cities, but one of the most important challenges that faces cities nowadays is the waste processing. And there are two factors directly affect this challenge are: the increasing of urban areas and the rapid growth of population. So, it seems evident, the investment in involving the citizens in the interaction with any future waste management system will save a lot of money and efforts. Especially, in the developing countries, citizen needs some encouragement to interact with modern systems and make him use it in everyday life.

Due to the growth of IoT technology, there is an increasing need and importance to design and implement waste management systems that attract and involve the citizens in the waste management process.

The aim of this paper is to present the design of attractive waste management that uses IoT devices, RFID tags, weight and ultrasonic sensors to measure the citizen interaction with the waste management process.

Keywords— Wase Management systems, RFID, IoT.

I. Introduction

Due to the rapid increasing of population as well the increasing of the urban areas in cities nowadays, waste management considered as one of the most important factors that affect the economy. Because providing an effective and efficient system to the citizens becomes a challenge for the municipalities due to lack of financial recourses [1].

Therefore, solving such problem should be solved by involving different aspects together: social, technical and financial [3]. For example, it seems evident that the citizen awareness and attraction should be involved with technical solutions.

Since the rising importance of waste management systems on the environment and human health and due to the growth of technology such as the presence of IoT and RFID, many researchers tried to design waste management systems.

in [2], an RFID based waste management system was presented such that each waste bin contains an RFID tag. Where the driver of the truck that collects the bins has PDA with RFID reader that helps the driver to collect the information of each bin he dumped in the truck.

In [4], an advanced Decision Support System (DSS) for efficient waste collection in Smart Cities is proposed. The system incorporates a model for data sharing between truck drivers on real time in order to perform waste collection and dynamic route optimization. The system handles the case of ineffective waste collection in inaccessible areas within the Smart City.

In [5], the proposed system consists of smart bins, such that each smart bin consists of fill out sensor and IoT unit. Such that the sensors detect the filling level of the bin and the IoT sends these reading to the cloud. in the control center, the readings from the bins are analyzed and the best route for the waste collecting truck is generated based on the bins locations and filling levels. And the route information is forwarded to the truck collection driver.

In this paper we will present the design of a waste management system that focuses on the social aspects of the waste management systems such that our system uses IoT devices with RFID tags, weight and ultrasonic sensors to measure the citizen interaction with the waste management process.

The rest of the paper is organized as follows: in section II system architecture, section III components interaction and in section IV conclusion.

II. System Archetecture

In this section, we will propose a waste management system that focuses on the attraction for the citizens through interaction and encouragement to make citizens more collaborative in the waste management process.

In this system, each bin will be equipped with an IoT device, weight sensor, ultrasonic sensor, solar cell, RFID reader and two light emitting diodes as indicators, such that one of these indicators colored by red and the other colored by green. Where every citizen who wants to interact with the system should have an RFID card associated with a credential for the citizen, such that the credential contains his mobile

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number and password. Each time the citizen wants to put trash in the bin, he should use the RFID card for identification to the RFID reader attached to the bin. And the weight and ultrasonic sensors measure the weight and the size of the trash inserted to the bin. Then, the IoT unit attached to the bin sends these readings to the application server and the citizen receives an acknowledgment about the transaction completion either by SMS or through push notification on a mobile application. Moreover, the citizen credential is used to let the citizen to log on to the system through the web application or through the mobile application to monitor his interaction history and his awarded points. Where the awarded points to every citizen can be converted to municipal facilities or services.

In addition, each waste collecting truck is dedicated for a specific geographical zone(s), such that the driver has a tablet with an application installed to show him the filling state of the bins allocated on a map for the specified geographical zone. In addition, each waste collecting truck has an IoT unit connected to a microcontroller to control the dumping and evacuation process, such that, the truck cannot dump a bin unless the truck and bin are on the same location, as well, the truck cannot perform the waste evacuation process unless the truck reached the waste evacuation station.

On the other hand, the IoT unit in each bin synchronously and asynchronously sends the filling state of that bin to the application server. Such that the filling state information is sent periodically as well every time a citizen inserts trash in the bin. The application server in turn forwards this information to the waste collecting truck and displays that information on the tablet application map. Moreover, each waste collecting truck sends synchronous updates, such as location updates to the application server. As well each waste collecting truck sends asynchronous updates to the application server, such as, when the truck performs bin dumping or waste evacuation. Moreover, each waste collecting truck contains an IoT unit and a controller to control the waste evacuation door and the dumping engine, such that, the evacuation door cannot be opened unless the truck is inside the waste evacuation station as well the dumping engine will not run unless the truck in the same location as the desired bin.

Let us now to conclude the system main components, as shown in Fig.1, the system consists of:

1) Weight sensors: each bin contains a weight sensor to detect the weight of the trash inside the bin.

2) Ultrasonic sensors: each bin contains an ultrasonic sensor to detect the volume of the trash inside the bin.

3) RFID readers: each bin has an RFID reader attached to let the citizen be identified to the system through his RFID card.

4) RFID cards: every citizen wants to interact with the system, should have an RFID card to let that citizen be identified to the system.

5) IoT Units: each bin contains an IoT unit that collects the readings from the sensors as well from the RFID reader and sends that readings to the application server through the internet.

6) Solar cell: each bin has a solar cell attached in order charge the battery of the attached IoT unit.

7) Application server: a cloud based hosted application server that contains a MYSQL database of the system as well PHP to interact with the IoT units, citizens and with the drivers of the trash collecting trucks.

8) GIS server: GIS servers some time may be needed to to provide a custom map service in case the region is not fully covered by a third party mapping service such as google.

9) Tablet application inside the waste collecting truck: this application helps the driver to browse the trash bins in the geographical zone and the filling state of each bin.

10) IoT unit inside the waste collecting truck: this unit is connected to a microcontroller to control the waste evacuation door and the dumping engine.

11) Accelerometer inside the bin: this accelerometer is used to notify about any movement of the bin. In addition, it is used to verify the starting and ending of the dumping process.

Thereafter, we will now describe the database entities, where the database contains the following tables: -

1) Bin_Update: this table is used to store the bin latest information sent by the IoT unit. Therefore, it contains the following columns: -

- Bin_ID: this column is used to store the ID of each bin.
- Current_Weight: to identify Current Weight of the bin.
- Filling_Status: this column is used to store the filling percentage of the bin, such that, if the bin is fully filled then this column contains 100 for that bin.
- Time_stamp: this column is used to store timestamp of the latest update received from the bin.
- Latitude: this column is used to store the latitude for the latest known location of the bin.
- Longitude: this column is used to store the longitude for the latest known location of the bin.
- Battary_Level: this column is used to store the battery level of IoT unit.
- Last_Dump_time: this column is used to store the timestamped of the latest dump performed for the bin.
- Truck_ID: this column is used to store the id of the waste collecting truck which performed the latest dump operation on the bin.

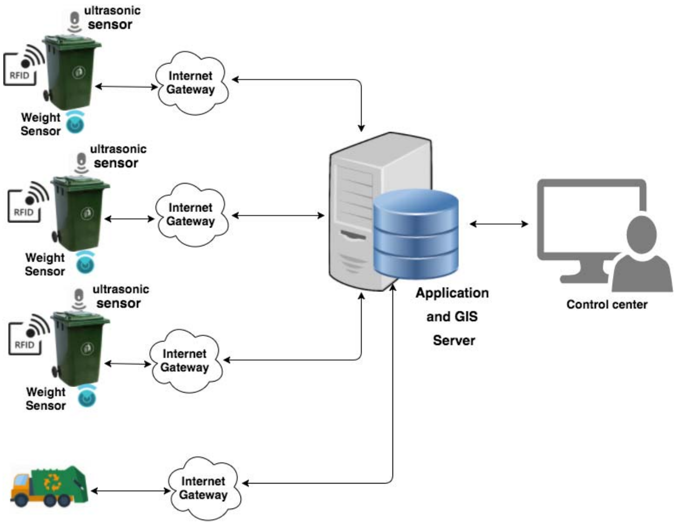

Fig.1:System main components and interaction between these components

2) Bin_info:this table is used to store the bins management information. Therefore it contains the following columns:

- Bin_ID: this column is used to store the serial number of the bin.
- Bin_Capacity: this column is used to store the bin capacity.
- IoT_Device_ID: this column is used to store the mac address of the IoT unit attached to the bin.
- Zone_ID: this column is used to store the id for the geographical zone which the bin is located in.

3) Waste_Collecting_Truck_Trackig: this table is used to record the operations of each waste collecting truck operations, therefore it contains the following columns:

- Truck_ID: this column is used to store the id of the truck.
- Latitude: this column is used to store the latitude for the latest known location of the truck.
- Longitude: this column is used to store the longitude for the latest known location of the truck.
- Operation_ID: this column is used to store the id of the operation that being performed by the truck, such that it stores 0 for location update, 1 for bin dumping and 2 for waste evacuation.
- Time_stamp: this column is used to store timestamp of the latest update received from the Truck.

4) Truck: this table is used to store the waste collecting trucks management information. Therefore it contains the following columns:-

- Truck_ID: this column is used to store the tuck plate number.
- Station_ID: this column is used to store the id of the waste evacuation station at which the truck should evacuate the waste.
- Capacity: this column is used to store capacity of the truck

5) Stations: this table is used to store the waste evacuation stations management information. Therefore it contains the following columns:-

- Station_ID: this column is used to store the id of the waste evacuation station.
- Station_Name: this column is used to store the name of the waste evacuation station.
- Latitude: this column is used to store the latitude for the waste evacuation station.
- Longitude: this column is used to store the longitude for the waste evacuation station.

6) Zones: this table is used to store the geographical zones management information. Therefore it contains the following columns:-

- Zone_ID: this column is used to store the id of the geographical zone.
- Zone_Name: this column is used to store the name of the geographical zone.
- Min_Longitude: this column is used to store the minimum longitude of geographical zone.
- Min_Latitude: this column is used to store the minimum latitude of geographical zone.
- Max_Longitude: this column is used to store the maximum longitude of geographical zone.
- Max_Latitude: this column is used to store the maximum latitude of geographical zone.

7) Citizen_Points:this table is used to store the citizen collaboration log and the awarded points for that citizen, such that each time a citizen put a trash in a bin, a new row in this table is inserted:-

- Citizin_ID: this column is used to store the id of the citizen which could be his mobile number.
- Trash_Weight: this column is used to store the weight of the trash that the citizen put in the bin.
- Trash_Size: this column is used to store the size of the trash that the citizen put in the bin.
- Bin_ID: this column is used to store the id of the bin at which the citizen put his trash.
- Awarded_Points: this column is used to store the cumulative awarded points to the citizen.

III. COMPONENTS INTERACTION

In this section, we will describe the interaction between system components. Therefore, firstly we will show the the interaction performed when a citizen puts trash in the bin. As shown in Fig.2:-

1) The citizen puts his RFID card close to the RFID reader attached to the bin.

2) The IoT unit attached to the bin sends the RFID information entered by the RFID reader to the application server.

3) The application server checks wither the RFID information is registered for a certain citizen or not. If yes, the application server sends to the IoT unit that the citizen is identified, then the IoT unit signals the green led to light. If no, the application server sends to the IoT unit that this citizen is not identified, then the IoT unit signals the red led to light.

4) On the bin there are two leds; green led and red led. Therfore if the received reply from the application server that the citizen is identified, then the green led will light. And if the received reply that the ciziten is not identified, the red led will light.

5) Once the citizen ovserves the light of the green led, he put the trash in the bin.

6) After the citizen puts his trash in the bin he will receive either an SMS or push notification message that comfirms the process success.

Secondly, we will show the interaction performed between the system components when the filling status of the bin reaches certain threshold. As shown in Fig.3, each bin sends the filling status with in synchronous and asynchronous update to the application server. Consequently, the application server updates the color of each bin on the map of the tablet application located in the waste collecting truck. Such that as long as the filling status is below 50%, the color of the bin stays green. If the filling status is between 50% and 80%, the color of the bin stays yellow. But, once the filling status reaches 80%, a continuous alert with dropdown list starts on the main screen of the tablet application and the color of the bin icon on the map becomes blinking red.

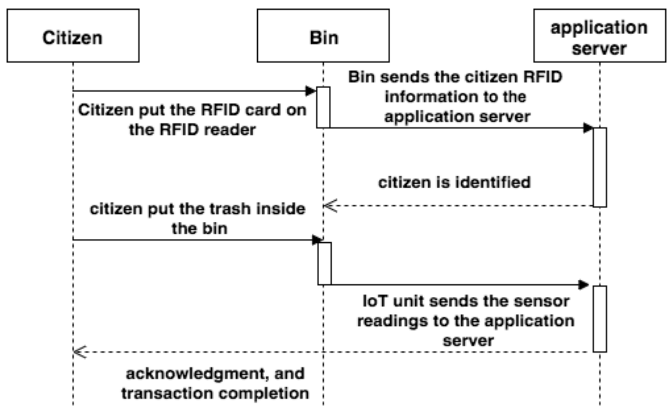

Fig.2: interaction when citizen puts trash in the bin.

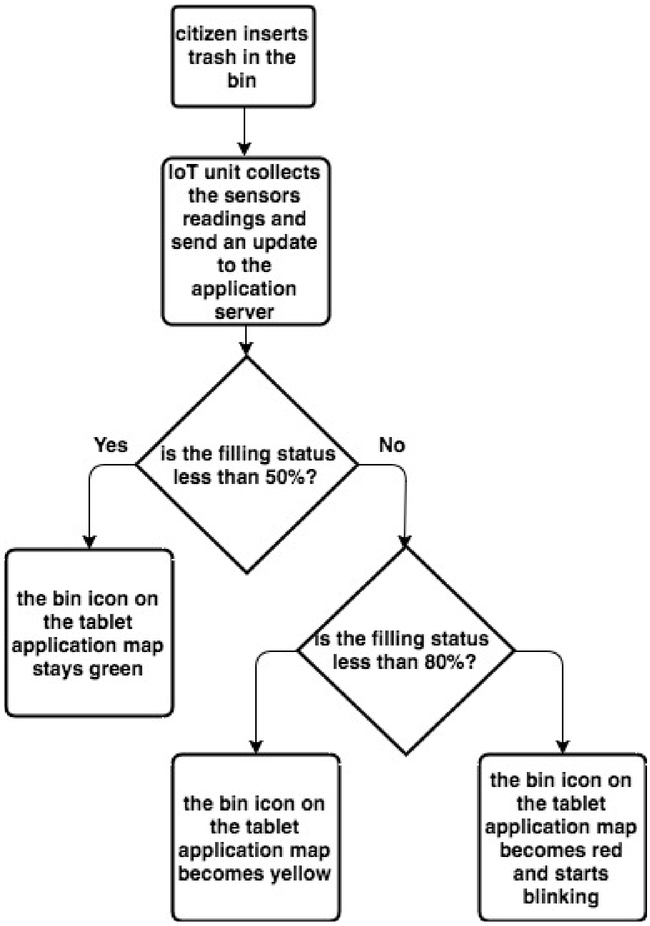

Fig.3: Interaction flowchart when filling status reachs certain thresholds

Thirdly, we will show the interaction process performed by the waste collecting truck. The truck sends synchronous updates to the application server such as location updates. As well it sends asynchronous updates each time an operation performed such as bin dumping or truck waste evacuation. As shown in Fig.4, once the truck reaches a bin to be dumped, the driver clicks the icon of that bin on the map. Then the application verifies wither the truck and the bin are in the same location. Once the location is verified, the dumping process starts and both the truck and the bin send asynchronous update to the application server, such that, bin detects the starting of the dumping process through an accelerometer. Therefore, if a waste collecting truck already sent a bin dumping location verification, then the dumping process starts smoothly. But, if there is no truck is already sent a bin dumping location verification, that means a theft or illegal movement is being performed on on the bin and the system fires an alarm. Once the Truck being full and it needs to evacuate the waste, the driver presses the evacuate button on the tablet application, the truck sends an asynchronous update to the application server, where the application server decides wither the truck is inside the waste evacuation station or not. If the Truck is inside the waste evacuation station, the application server sends a command to the IoT unit inside the truck to alter a controller to open the evacuation door.

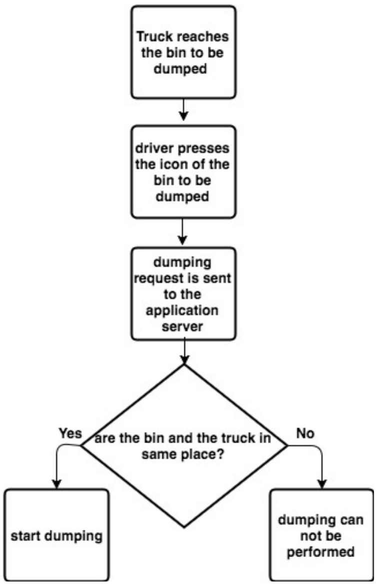

Fig.4:Location verification before dumping starts

IV. CONCLUSION

In this paper, the design of an attractive waste management system has been stated. Such that it involves the citizen in the waste management process by using using IoT unit on each trash bin, such that, the bin is equipped with an RFID reader, weight sensor and ultrasonic sensor to evaluate the citizen interaction with the system and give him points according to that interaction. Moreover, our system provides a control mechanism for the waste collection trucks, such that it has a control that verifies the location for dumping and evacuation processes before it permits any process to start.

Our future work, to to introduce algorithms that take in consideration the filling rate of each bin, the truck location and the shortest path in order the threshold for each bin as well to optimize the bin dumping process.

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