A Cloud integrated wireless garbage management system for Smart Cities

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Abstract— **Waste management is an issue of serious concern in modern urban scenario with exponentially rising population. Apart from the need to reduce the costs incurred in garbage management, the municipality, at the same time has to ensure a safe and healthy environment for the citizens. This paper presents the development of a cloud integrated wireless garbage management system for smart cities. The proposed system centrally monitors the temperature, humidity, flammable gases concentrations (or smoke), fire detection and garbage fill volume in waste bins with the help of wireless sensing nodes placed at remote locations in the city. The communication from the sensor node to the central station is done using TCP/IP protocol via existing GSM/GPRS wireless infrastructure in the city. At the cloud server, the data is monitored, analysed and stored and notification to the service providers is sent for suitable action for fire prevention and waste bin overflow. The experimental results show that the proposed system is a cost-effective and efficient solution for waste management in modern urban scenario.**

Keywords—clean and green environment; sustainable living; smart bin; GSM/GPRS; Internet of Things; wireless network; arduinoMega; smart city; cloud; android app.

I. INTRODUCTION

The term smart city is used to refer to technology-intensive cities that can offer collection, analysis, and dissemination of information so as to transform services offered to citizens, increase operational efficiency, and entail better decisions at the municipal level [1]. Connectivity plays a major role in smart cities to enable interoperable access and interconnection among heterogeneous smart city objects [2]. The existing telecommunication infrastructure in cities, and technologies, such as cloud computing, wireless sensor networks, Internet of Things can together deliver efficient services to the citizens. The exponentially increasing industrial and municipal waste management is one of the major concerns in modern urban scenario. The traditional and manual method for waste bin pick-up scheduling is not optimal and also lacks proper systematized mechanisms to identify and prevent thriving ambient conditions for germs breeding, fire accidents etc. The environment conducive to the above mentioned dangers in waste dumpers is mainly governed by temperature, humidity and flammable gas concentration combinations. So, there is a need for a central automated wireless tele-monitoring and notifying system for an optimal and safe waste management in the cities.

Recently, a number of systems have been reported in literature for smart waste management. In [3], Waitkus implemented a remote bin monitoring and trash pick-up scheduling system to monitor the container fullness, notify the waste hauler and schedule trash pick-up based on customer preferences. In [4], Porat et. al. measured the fill volume of bins using volume sensors, lasers, photodetectors and send the information to garbage collectors to schedule the pick-up accordingly. In [5], Chowdhary et. al. used RFID tags and load cell sensor technology for trash handling. In [6], ultrasonic sensor measures the trash volume in the bin, send the data to the server through wireless mesh network. In [7], Thakker et.al. segregated the plastic waste and biodegradable waste using NIR spectroscopy and the system also notifies the garbage collector when the container is about to fill. In [8], Arebey et. al. implemented an RFID, Geographical Information System (GIS), application framework for managing trash pick-up vehicles in real time.

Many of the above mentioned works involve cumbersome implementations and/or expensive solutions. Thus, there is a need for developing a system based on simplicity, low-cost and ubiquitous infrastructure availability. Work in that direction was carried out by authors in [9] which presented the implementation of an optimal trash pick-up scheduling system using ultrasonic sensor technology where notification for garbage collection is sent by SMS sent via GSM network. As an extension of the earlier work [9], the present paper presents a complete solution for safe bins and waste management in smart cities. The system proposed and implemented in this paper is an easy to use, reliable, low cost, easily deployable and scalable system. Apart from a central monitoring and notifying station, the system proposed and implemented in this paper also includes an android application installed on mobile phones of workers for real time monitoring and action.

The paper is organized as follows: Section II gives the overall architecture of the proposed system. Section III and IV provide the hardware and software details used for system implementation, respectively. Section V describes the system implementation and deployment. The results and conclusions are shown in sections VI and VII, respectively.

II. System Architecture

Fig. 1 shows the general architecture of the proposed cloud integrated wireless garbage management system framework whose implementation includes following elements:

a) Wireless Sensing Node – This unit is located in each smart bin in the city. It comprises sensors that collect ambient data from the bins, a microcontroller that samples the sensed data, a wireless module that transmits the data to the central station.

b) Cloud based server- This is a connected Web entity that receives, stores, displays and analyses the information provided by the various wireless sensing nodes in real time. It also notifies the workers for suitable action.

c) Software Android App – This is an application software system. The workers install it on their smart phones for mobile live monitoring of bins and hence take suitable action.

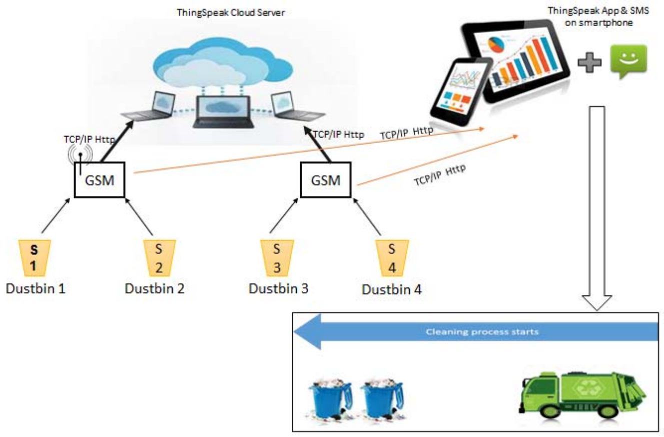

Figure 1. General Architecture of Cloud integrated Wireless Garbage Management System Framework

III. Hardware Implementation

The proposed cloud integrated wireless garbage management system is composed of microcontrollers, sensors, LCD display module, GSM/GPRS wireless transmission module at each smart bin and a central monitoring PC/server that receives information from each smart bin in the city.

A. Microcontroller

The smart bin monitoring system uses an Arduino Mega2560 microcontroller based on the ATmega1280. The board is powered by 5V supply supplied either at VIN via an on-board regulator or USB or some other regulated 5V supply. It operates at CPU frequencies of upto 16 MHz. It includes upto 128 KB of flash memory, upto 8 KB of SRAM memory, USB Device interface, SPI interface, I2C-bus interfaces, UARTs, 54 digital input-output pins and 16 analog input pins.

B. Ultrasonic Sensors

The ultrasonic ranging module, HC-SR04 is used in this work for garbage volume sensing in bins due to its low cost and good accuracy. It comprises ultrasonic transmitters, receiver and a control circuit, powered by a 5V supply. A high-level voltage signal is applied for 10 microseconds at the input pin of sensor which generates eight 40 kHz burst pulses which hit the target object and return. The module detects the returned pulses. The fill volume is inversely related to the time delay elapsed between transmitted ultrasonic burst and received echo signal. The HCSR04 connections and working principle are shown in Fig. 2. The measurement range of the sensor is 2-400 cm with an accuracy of 3 mm and 15° angle of coverage [11].

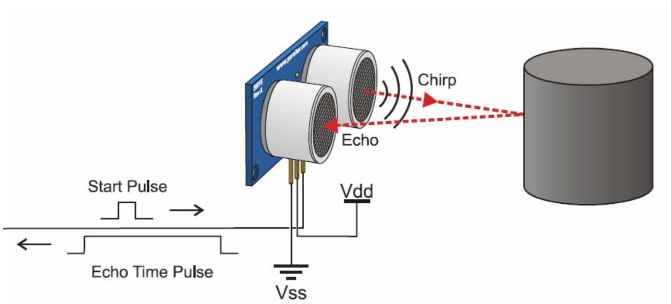

Figure 2. Sketch of working principle of the Ultrasonic Sensor

C. Smoke Sensor

MQ2 Gas Sensor module is used in this work for detecting flammable gases H_2, LPG, CH_4, CO, Alcohol, Smoke or Propane. This sensor uses SnO2, which has lower conductivity in clean air. When the targeted flammable gas is present, the sensor's conductivity gets higher as the gas concentration rises. This change of conductivity may be converted to corresponding voltage output signal of gas concentration through a simple circuit. The sensor has large measurement range (300-10,000 ppm), high sensitivity, fast response time. The sensitivity of the sensor can be adjusted by potentiometer [12]. The output can be an analog signal (A0) that can be read with an analog input of the Arduino or a digital output (D0) that can be read with a digital input of the Arduino. Details of the interfacing circuit of MQ2 gas sensor is shown in Fig. 3.

D. Temperature & Humidity sensor

The DHT11 sensor used in this work detects water vapour by measuring the electrical resistance between its two electrodes. The humidity-sensing component consisting of a moisture holding substrate with electrodes is applied to the surface. When water vapour is absorbed by the substrate, ions are released by the substrate, which increases the conductivity between the electrodes. The change in resistance between the two electrodes is proportional to the relative humidity. Higher relative humidity decreases the resistance between the electrodes. The DHT11 module measures temperature with a surface mounted NTC (negative temperature coefficient) temperature sensor (thermistor) built into the unit [13]. The measurement ranges of the sensor are 20-90% RH and 0-50°C temperature with sensitivities of +-5% RH and +-2°C temperature. The circuit diagram of DHT11 sensor interfacing with Arduino Mega is shown in Fig. 3.

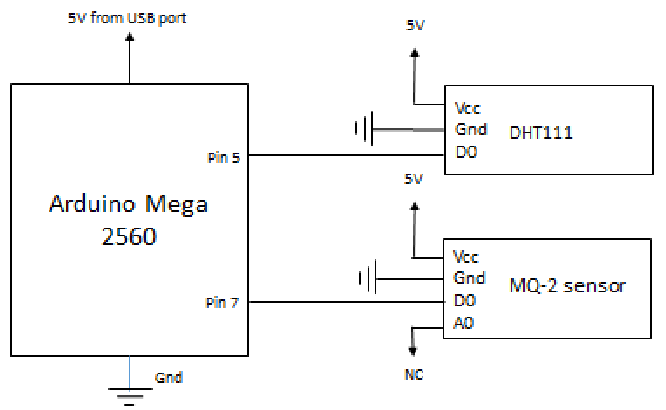

Figure 3. Interfacing MQ2 gas sensor with ArduinoMega

E. LCD Display

A 16 x 2 alphanumeric dot matrix LCD displays is used in this work. The details of interfacing the LCD with ArduinoMega is shown in Fig. 4.

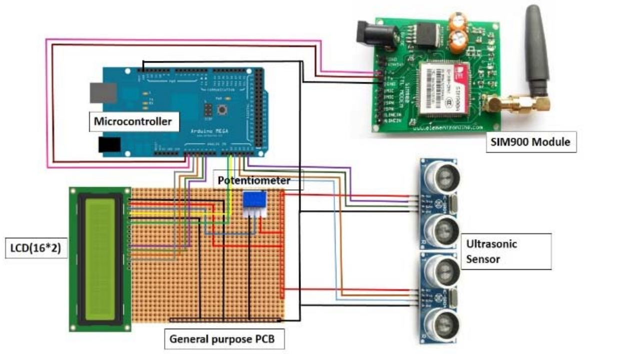

Figure 4. Interfacing LCD display and GSM shield with ArduinoMega

F. GSM shield and modem

The microcontroller is connected wirelessly to the remote cloud based server using an arduino compatible GSM shield. A Subscriber Identity Module (SIM) card provided by a network provider is inserted in the shield for connecting to the cellular network [14].

G. Cloud Server(ThingSpeak)

In the simplest terms, cloud computing means storing and accessing data and programs over the Internet instead of the computer's hard drive. The cloud is just a metaphor for the Internet. Cloud servers are virtual servers which run on cloud computing environment. That is why very often cloud servers are referred to as virtual dedicated servers (vds).

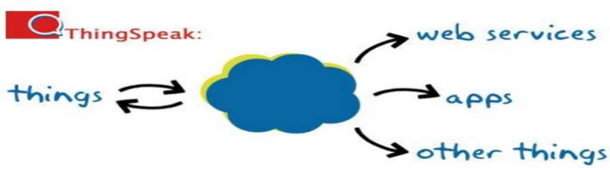

Figure 5. ThingSpeak cloud server features.

ThingSpeak is an IoT analytics platform service that enables aggregation, visualization and analysis of live data streams in the cloud as shown in Fig. 5. With the ability to execute MATLAB code in ThingSpeak, online analysis and processing of the data may be done as it comes in. The cloud may perform event detection and issue notifications based on requirements to the clients / service providers [15].

IV. SOFTWARE DESCRIPTION

The Arduino Mega board is programmed using the Integrated Development Environment (IDE). The firmware uploaded on microcontroller includes two main parts, real-time collecting of sensor data and wireless transmission. The ultrasonic, smoke (flammable gas), temperature and humidity sensors are first used to collect data which is then sent through GPRS wireless transmission module. The algorithm for the proposed system programming is shown in the flowchart in Fig. 6. Attention (AT) commands are used to enable communication of the GPRS transmission module with the mobile wireless network.

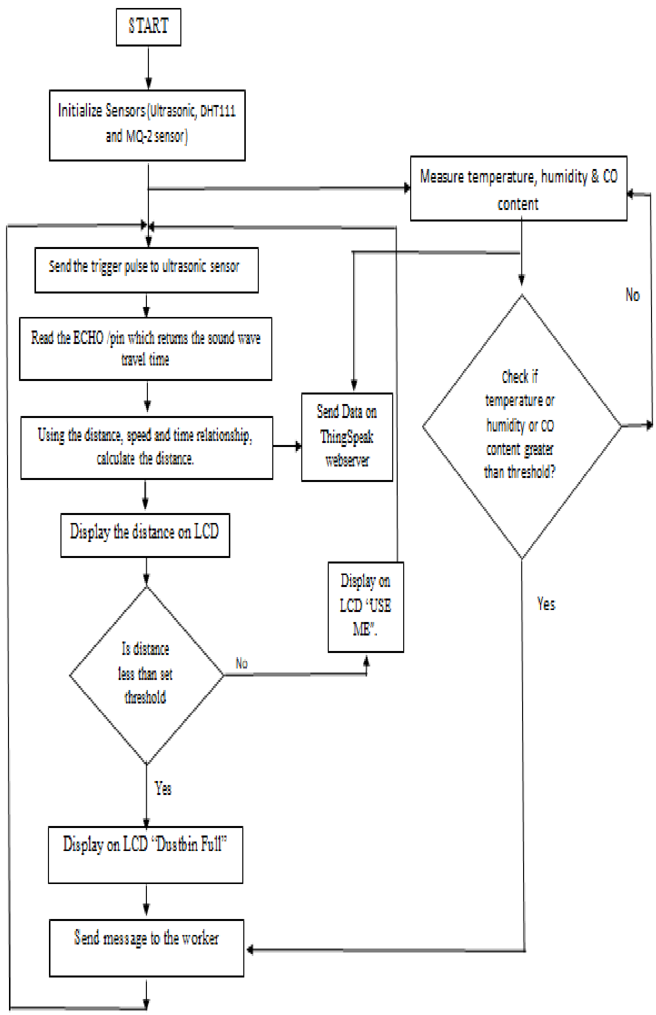

Figure 6. Sensor Node Routine

When the sensor node is powered ON, the microcontroller, attached sensors and GSM/GPRS module are initialised. The microcontroller then sends the command AT and checks whether the sensor node is attached to the GPRS service of the cellular network. Next, based on TCP/IP stack, it initializes GPRS wireless transmission module and sets the access point name; Next, the microcontroller sends the "AT+CIICR" command to start wireless GPRS connection and get the IP address assigned from the network. Finally, the TCP connection to the remote Thingspeak server is started using “AT+CIPSTART" command. Microcontroller samples the data of various sensors, including ultrasonic sensor, smoke concentration, temperature, humidity and displays the collected data on the LCD display module real-timely. Finally, the collected data is packed and transmitted wirelessly to the Thingspeak server via GPRS connectivity. When an abnormality is detected in the sensed temperature, humidity and smoke values or garbage level, the microcontroller sends an SMS via GSM network to the workers mobile phones.

V. SYSTEM IMPLEMENTATION & DEPLOYMENT

The implemented system prototype is shown in Fig. 7.

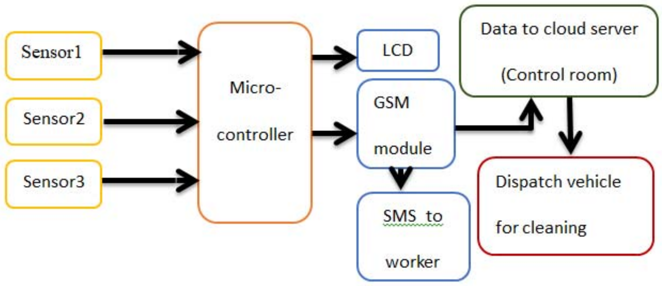

Figure 7. System Functional Block Diagram

When the system is switched ON and initialized, the microcontroller establishes a GPRS link with the mobile network. Next, it samples the smoke sensor, humidity and temperature sensor and ultrasonic sensor signals, forms packets and transmits wirelessly to the ThingSpeak server (control room) via GPRS connectivity. A message is sent to the worker responsible for cleaning/emergency action (like fire control, humidity, temperature maintenance in bins). The workers may also monitor the bin in real time on the Android app installed on their smartphones. The trash collector van schedules its pick-up / emergency action route accordingly.

VI. RESULTS

A snapshot of the implemented system prototype is shown in Fig. 8.

Figure 8. Testing of the Implemented System Prototype

A. *ThingSpeak web server*

The measured trash levels, bins temperature, humidity and smoke detector readings thus displayed on the Thingspeak server are shown in Fig. 9 and Table I.

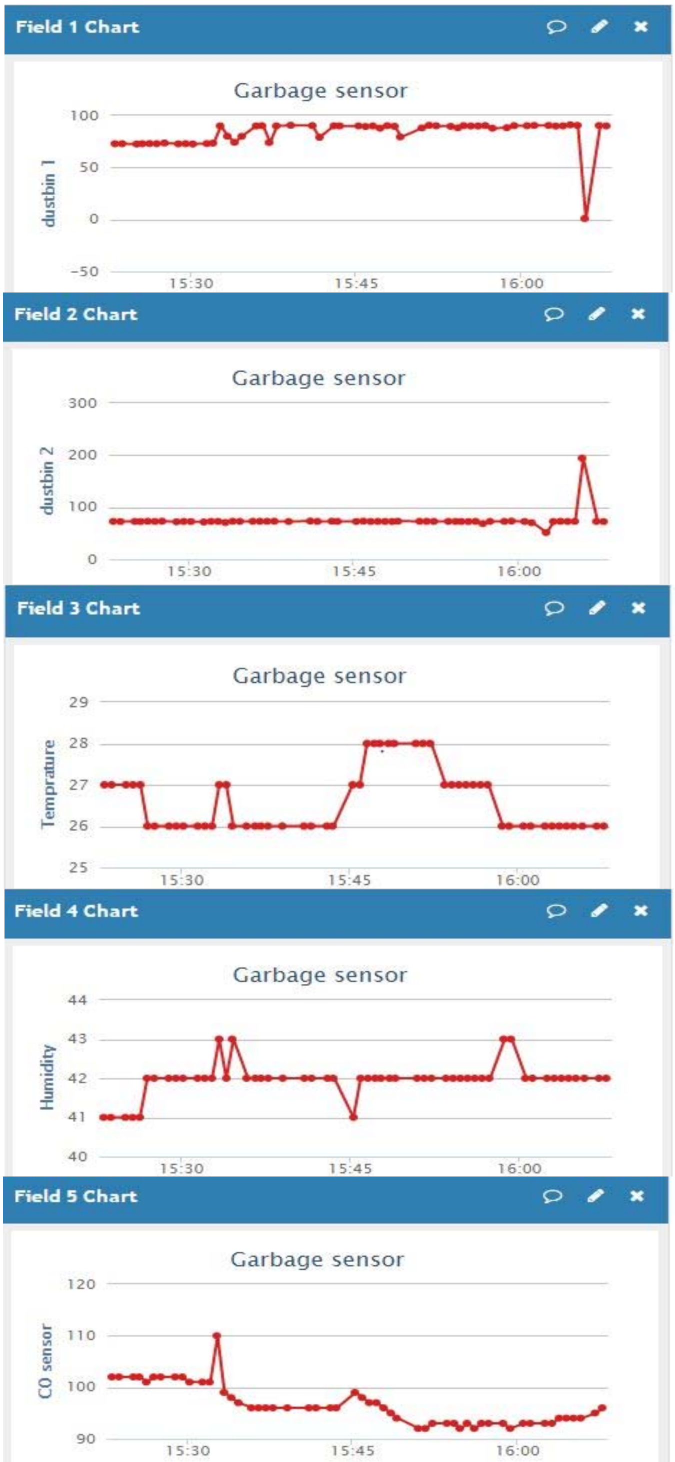

Figure 9. Received Sensor Data displayed on ThingSpeak server

TABLE I. Reading of different sensors collected by the cloud server

Entry	Garbage Bin1	Garbage Bin2	Temperature (ºC)	Humidity	Smoke
1	72.88	72.6	27	41	102
2	72.87	72.41	27	41	102
3	72.56	72.6	27	41	102
4	72.86	72.41	27	41	101
5	73.05	72.94	27	41	102
6	72.9	72.62	26	42	102
7	73.58	73.14	26	42	102
8	72.74	71.94	26	42	102
9	72.9	72.6	26	42	102

B. *ThingSpeak App:*

The transmitted sensor data can also be viewed on ThingSpeak app for immediate action by the service providers. The data displayed on ThingSpeak App is shown in Fig. 10.

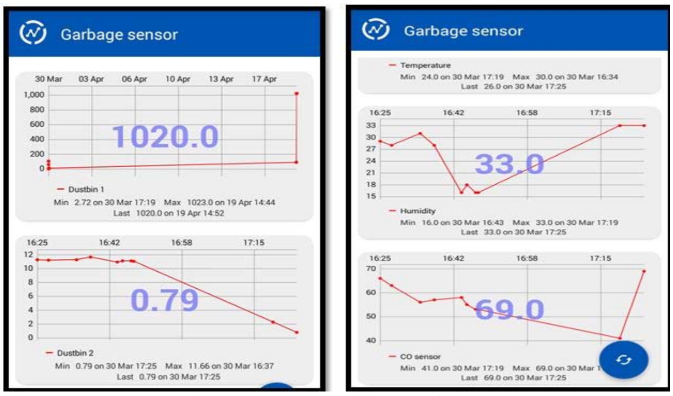

Figure 10. Data on ThingSpeak App

C. *Snapshot of message received on mobile*

The alert SMS received on mobile phone of workers / service providers is shown in Fig. 11.

Figure 11. Messages received on Mobile

VII. CONCLUSIONS

This paper has presented details of a successful implementation of a cloud integrated wireless garbage management system for a smart city. The system has been tested in a real situation. This system significantly reduces the average cost of maintaining a clean and safe environment in bins by optimising the waste bin pick-up schedule and also prevents dangers like fire and germs spread. More importantly, this system uses the existing communication infrastructure and free ThingSpeak cloud server services available in the city. Being wireless the system is easy to deploy and maintain. It may be noted that this system is particularly relevant for developing countries, like ours, as it presents a cost-effective, quick and efficient implementation. It also fits in nicely with the plans of many governments to not only implement smart cities but also growing importance of developing of apps which are being included in Telecom policies of many countries. The use of a solar or a piezoelectric energy harvester is suggested to prolong the battery life. This will lead to autonomous self-sustained operation of wireless sensing nodes for an extended period of time and hence improve the overall reliability and effectiveness of the proposed framework.

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