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An Ideal Wireless Waste Management System for Rural Settlements

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Abstract:
In most rural settlements in Nigeria and Africa, wastes are being dumped in open and central places without adequate disposal mechanism. With increasing population, the quantity and rate of generation of these wastes have become quite alarming these days. Lack of an efficient solution to waste management and disposal has often resulted to environmental degradation and outbreak of different diseases. In this paper, a critical survey of the existing systems of waste management and disposal is presented. The suitability of these existing approaches to Nigerian situation was examined. Lack of provision of means of sending information to designated agencies responsible for waste disposal in rural areas where GSM network is unavailable was identified as the problem that might limit the efficiency of the surveyed approaches in Nigeria. Most of the proffered waste management systems uses only GSM for sending waste level information to disposal agencies regardless of the fact that GSM is not available everywhere, especially in the rural areas of developing countries like Nigeria. In this paper, an ideal waste management system aided by an adhoc network using Radio Frequency module was developed and recommended for our rural areas.
Key Word: Adhoc network, GSM, Rural settlements, Smart bin, Waste disposal, Wireless

I. Introduction

Indiscriminate dumping of waste in open places without adequate disposal is one of the major challenges facing rural dwellers. The incessant outbreak of diseases such as cholera and other airborne diseases in the rural area may not be unconnected to this ugly practice. Outbreak of diseases in remote places where medical facilities and personnel are grossly lacking is always critical and often results to large number of deaths due to poor treatment. Besides, little or no attention has been given to this problem associated with poor waste management and disposal by the authorities responsible for such. The main reason for their negligence may be as a result of not being able to remotely monitor the waste. Waste associated problems can be handled through proper sanitation, provision of waste containers, remote monitoring and timely disposal of waste by the authorities concerned.

Monika et al. (2016) proposed a smart bin that comprises of microcontroller, ultrasonic sensor and GSM modem. The microcontroller interfaces the GSM modem and the ultrasonic sensor. The ultrasonic sensor checks the level of the refuse and triggers the GSM to continuously send alert to the authority until the refuse is disposed.

In Neha et al. (2018), smart garbage bin that is capable of separating dry and wet waste was proposed. The proposed garbage bin has other functionalities such as alarming and informing the authorized agent who then sends a message in the form of SMS to the waste collector through web application. Every bin in the proposed system has a unique identification number.

An IOT based garbage monitoring system was proposed in Komal et al. (2018). The proposed project was designed to assist in keeping villages and cities clean. Components of their proposed project include Arduino, ultrasonic sensor, Wi-Fi module, DC motor and power supply unit. The status of the waste is shown or displayed on HTML page of the web browser.

Sathya and Sangeetha (2018) built a smart dustbin that is based on IoTs and sensor technology. The ultrasonic sensor used in this proposed system serves dual purpose. One of the functions of the ultrasonic sensor is for detecting the presence of human being so that the dustbin will open and the waste dumped. Secondly it is also used to measure the level of the waste inside the dustbin. The garbage collector is alerted when the dustbin is filled up for immediate evacuation over the web using the IoTs modem.

In Mahajan et al. (2017), a system for real-time monitoring of garbage bins was proposed. The proposed IoT based "Smart Waste Management system uses a combination of sensors, and raspberry pi to monitor the

level of garbage in the garbage bin. When threshold level is reached, available data will be forwarded to the control station with the aid of the Wi-Fi module while the data is being updated promptly. An optimized route for the garbage collecting vans using the data regarding the garbage levels is followed to ensure fuel economy.

A project named smart garbage bin was proposed in Shubham et al. (2018). In the proposed project, an enhancement of normal dustbin was done using ultrasonic sensor for garbage level detection and GSM module for forwarding of updated status of the garbage to the user.

A project that manages garbage collection for Municipal Corporation was developed in Rupa et al. (2018). In their project, an IOT based embedded device attached to the dustbin which continuously detects the level of dustbin using ultrasonic sensor and update the status of dustbins in each area to the website designed for this management was built. This device has timer which is set to time the removal of waste after the delivery of alert message. At the expiration of the time and the waste bin is still not cleaned, report will be made to a higher authority.

In Kannapiran et al. (2017), a smart dustbin system for monitoring of waste was developed. Their system is Arduino based which operates using a local area network server. With the aid of ultrasonic sensor, the Arduino controller reads the levels of the dustbin. Ethernet shield of the Arduino forwards data to server.

Garbage monitoring system which makes a normal dustbin smart through the help of ultrasonic sensors for garbage level detection and sends message to the concerned authority via GSM was implemented in Ramchandar et al.(2017).

A PIC microcontroller based smart garbage bin that informs an authorized person when the bin is about to fill through GSM was proposed in Sridevi and Sangeetha (2018).

A smart trash bin that uses fuzzy logic algorithm based on Arduino was designed by authors in William et al. (2019). The design comprises of ultrasonic sensor for detecting the levels of trash, passive infra-red sensor for detecting human presence and Arduino for information processing. It also has LED which indicates yellow colour when the trash can is half filled and red colour when full. A buzzer was also added to produce alarm when the bin is full and the trash can is also locked.

In Fetulhak et al. (2018), a system that monitors the level of the garbage via an ultrasonic sensor and sends message to the authorized department for garbage collection with the aids of GSM was proposed. The system uses PIR sensor to detect human motion around a bin that is full and also blocks further addition of waste of the people coming to the garbage bin with trash while the bin is at full status and block adding of any more garbage to the bin through informing them by speaker. GSM and the sensors used are linked to the Arduino microcontroller. GUI was developed to monitor garbage bins related information for selected locations and message through the GSM is display on LCD. With this, the driver is directed on time by the authorized person to collect the trash.

The continuous generation of waste in the rural areas of developing countries and lack of a waste management system that guarantees communication in an environment where GSM network is sparingly available or not available at all motivated this work. From the reviewed literature the authors did not give attention to a situation where waste bins are located in places that do not have GSM network.

This paper, therefore, proposes an ideal wireless waste management system for rural settlements. The proposed system will employ an adhoc network arrangement to complement GSM in message transmission.

II. Material And Methods

Materials

The proposed system (Ideal Wireless Waste Management System) consists of Arduino microcontroller, proximity sensor, Radio Frequency (RF) module, Global System for Mobile communication (GSM) module, Global Positioning System (GPS) module and waste container. The Arduino microcontroller is the coordinating component which interfaces other parts of the system to actualize the main target of the system. In this proposed system, waste containers that are uniquely numbered are placed at different locations where garbage and trashes are meant to be dumped and are installed with the system. As garbage is being dumped into the container, the ultrasonic sensor continually checks the levels of the garbage inside the container. Once the garbage gets to the threshold level, that is the level that indicates when the container is full, the ultrasonic sensor will send the information to the Arduino microcontroller which activates the GPS to obtain the location information and the stored message is forwarded by both RF and GSM modules. If there is GSM network within the area, through GSM module, message is forwarded to the concerned authority. However, if GSM network is not available, the message is forwarded to another sub system with the help of the RF module.

The sub system comprises of GSM module, RF module and a lower cost Arduino microcontroller that links them together. These sub systems are placed within the communication range of RF technology for effective communication to take place. The reason for this ad hoc network arrangement is to take care of those

known areas where GSM network is sparingly available or not available at all. Immediately the message gets to a place that is having GSM network, it will be delivered to concerned agency via GSM module.

The ad hoc network arrangement in this proposed model is not to replace GSM but to supplement. The contents of the sent message include the location information of the waste bin, its unique number and the full notice information. At the arrival of the message, it will be the responsibility of the authorized personnel to inform the driver and his men to go and dispose the waste.

System architecture

The structural arrangement of components of the main system and the sub system of our proposed system are depicted in Figure 1 and Figure 2, respectively.

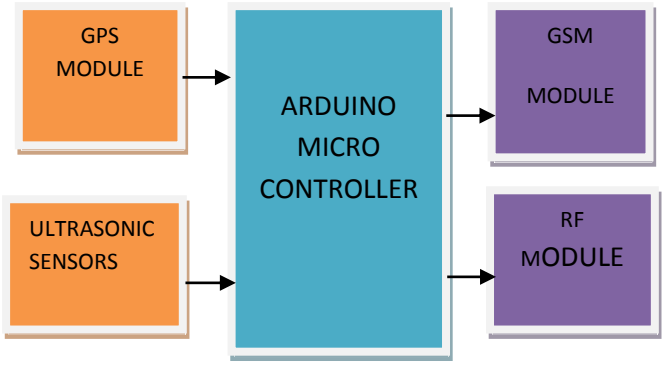

Figure 1 Block diagram of main system

Figure 2 Block diagram of subsystem

System circuit design

The possible circuit diagram of the proposed system which was designed using Proteus and with the help of peripheral tools is shown in Figures 3 and 4 for the main system and sub system respectively. Proteus is an electronic software that provides the platform for drawing, designing and simulation of project circuit. The schamatic construction on the proteus software makes project design and simulation cost-effective minimizes errors.

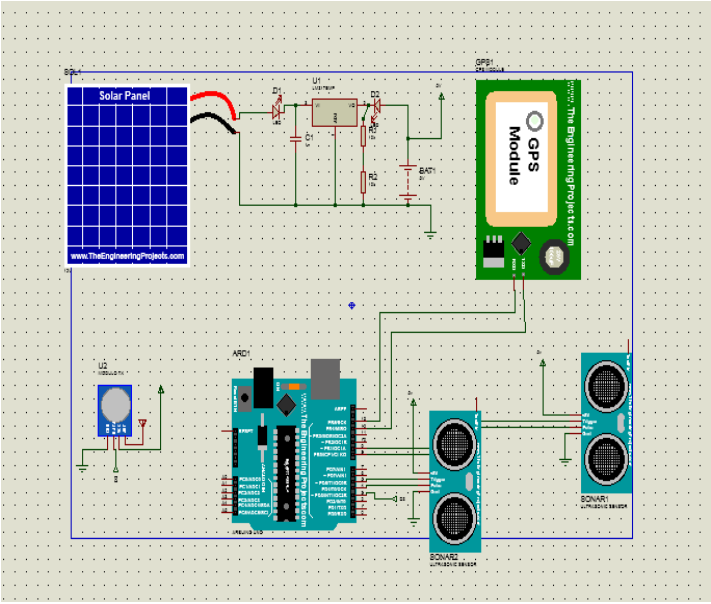

Figure 3 System circuit diagram of main system

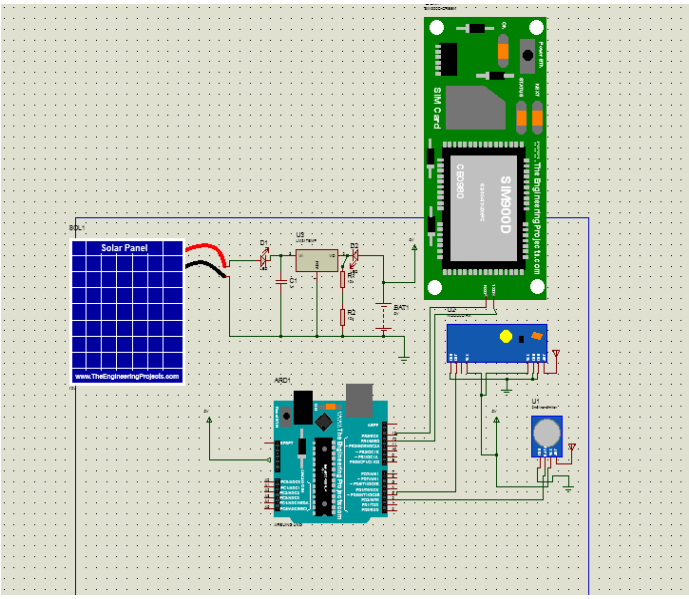

Figure 4 Circuit diagram of the subsystem

Proteus was used in this project because of the following benefits (Chengcheng et al.. 2018).

i. It has intelligent principle layout.
ii. It is good for hybrid circuit simulation and also guarantees accurate analysis.
iii. It is a software for single-chip debugging.
iv. It allows single-chip and peripherial circuit co-simulation.
v. It provides printed circuit automatic layout and wiring.

To accomplish the project design and simulation, the following steps were taken:

i. The proteus software was opened and new file was selected to display the drawing sheet.
ii. From the componet mode, all the necessary components for the project were selected using the object selector
iii. The circuit layout of the project was made and components of the circuit were connected using wires.
iv. The libraries of each componet was added.
v. The run button was selected to observe the working of the circuit.

System Implementation

The following procedures were followed in implementing the proposed system.

Choice of Development Environment

Proteus has an interesting, integrated and easy to use suite of tools for Programmable Circuit Board (PCB) design. The first step in designing the system hardware is by adding electronic shield, sensors and other components to the schematic via peripheral gallery. Hence, the proposed system was designed, tested, debugged and simulated inside Proteus schematic capture before identification and selection of suitable devices for physical prototyping. Proteus was our choice of development environment because of the flexibility in the product configuration.

Choice of Programming language

The choice of programming language in this project is Arduino. It is a platform with which we can build electronics projects. It comprises of circuit board which is programmable and software or an IDE that runs well on computer where codes can be written and uploaded to a physical board. With USB cable, Arduino can transfer new code into the board unlike most PCBs that will require programmer hardware. Learning and programming with Arduino IDE is easy because it makes use of simplified version of C++. The choice of Arduino is based on the following reasons (Louis, 2016):

i. Arduino software is open source.
ii. It is simplified, easy to learn and program
iii. The hardware boards are cheap
iv. It works well with other components of the proposed system.

System prototype

A system is a collection of different devices that collaborate in order to perform a specific task. We have two categories of systems in our work namely, main system and the sub system, each having its components as shown in Figures 1 and 2 respectively. The main system comprises of the Arduino microcontroller, ultrasonic sensor, GPS, GSM and RF modules whereas the sub system consists only of a lower cost Arduino microcontroller, GSM and RF modules. The sub system is not playing any monitoring role rather, it only facilitates the forwarding of message to the concerned agency where or when GSM network is not available. This is the main reason why it does not contain the ultrasonic sensor and the GPS module. Various components of each of these systems were properly interconnected using wires and all connections are firmly soldered together. Arduino software was developed to drive the systems. The software of the main system specifies a threshold which is the level of waste that will trigger message sending. The program contains a mobile phone number which is the destination of the sent message. Each of the microcontrollers was uploaded with the appropriate software programmed for its proper functioning. With this proposed system, monitoring of waste level and forwarding of message to the appropriate authority for immediate disposal can be achieved. Figure 5 and 6 shows the developed prototype. The ultrasonic sensor attached to the system is shown in Figure 5.

Figure 5 System prototype open view

Figure 6 System prototype closed view

III. Result

At the end of the implementation, testing of the systems was carried out to verify their functionalities. In our first test of the systems, two main systems were deployed; one was fixed on the cover of a waste container and the other at a communicating distance away from the sub system. The sub system was also deployed at an interval away from the waste container, though within a communication range. Then, waste was gradually loaded inside the container and when the loaded waste got to a certain level (threshold); double alert messages indicating that the waste bin is full were received on the mobile phone housing the SIM card with the designated number. One of the messages came direct from the main system and the other came through the sub system. The reason for the double messages was for the fact that the waste bin was placed where there is GSM network, thus both the direct message from its GSM module and message forwarded from the main system to the sub system through their RF modules was equally sent to the designated number.

A second test was conducted by placing the waste-bin fixed with the main system in a place where GSM network was not available. Then, a number of sub systems were placed in different locations within the communication range of their RF modules to take care of message transfer within the areas where GSM network does not exist. Then another main system was deployed after the last sub system to enable the transfer of

message to the designated number via GSM module. We made sure that the sub systems covered the whole areas where GSM network does not exist. When the waste bin was loaded up to the threshold level, it was noticed that only the alert message forwarded through the sub systems was sent to the designated phone number. The message from the main system could not be delivered because it was outside the GSM network coverage. It is the nonexistence of GSM network in certain locations within the rural areas that formed the basis of our work so that message notification for waste disposal will not be completely lost. Fig. 7 shows message alert.

Figure 7 Message alert

IV. Conclusion

Systems that solve the problem of sending waste disposal message in an area where GSM network does not exist was successfully designed and implemented in the study. Two test conditions carried out to establish the functionalities of the systems showed that the identified gap in literature could be bridged with the developed systems. Cost is the major challenge in the study, though cannot be compared to healthy living in the society.

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