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Simulation Model for a Real Time Solid Waste Bin Monitoring System

¹Md. Abdulla Al Mamun, ¹M.A. Hannan, ¹Aini Hussain, ²Hassan Basri

¹Department of Electrical, Electronic and Systems Engineering, Faculty of Engineering & Build Environment, Universiti Kebangsaan Malaysia, 43600, Bangi, Selangor, Malaysia

²Department of Civil and Structural Engineering, Faculty of Engineering & Build Environment, Universiti Kebangsaan Malaysia, 43600, Bangi, Selangor, Malaysia

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ABSTRACT

This paper presents a unique solution for real time solid waste bin status monitoring system. The system is based on a three tier architecture that uses wireless sensor networks. A number of sensory equipment are used to perceive the bin status where ZigBee and GPRS are used as communication technologies. In the physical architecture, the first tier contains smart bins to measure and transmit bin status parameters. In the second tier, gateways are used for storing and forwarding bin data to a remote server. A control station resides in the third tier to store and analyze the bin data. Based on the physical architecture, a simulation model have been designed and simulation is performed using Castalia to ensure the feasibility and accuracy of the system. Simulation result shows that, the proposed system would be able to monitor bin status on real time that can help to automate the solid waste monitoring process for the purpose of collection optimization.

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INTRODUCTION

The depletion of resources in the current world is beyond control. Due to the rapid increase in population and urbanization, problems related to solid waste has increased day by day (World Bank, 1999). It is projected that the amount of solid waste will increase near 1.8 million tons per day by the year 2025 (Hoornweg, 2012). In the solid waste management process, waste collection and transport have become a considerable issue due to their impact on social health by emitting pollutant gas along with traffic and noise. Unusual use of vehicles for collecting waste expends more fuel which in turn produce a substantial amount of greenhouse gas (GhG) (Zhao, 2009). The number of collection increases when the partially fill up bins are collected. So it is very much needed to optimize the collection process by knowing the accurate information about a bin in advance (Faccio, 2011).

So far some researches have been investigated on monitoring the solid waste bin status. Different types of modern information and communication technologies have been used to measure and monitor the waste bin (Hannan, 2011; Arebey, 2010; Longhi, 2012; Rovetta, 2009). But the designed systems need much operation costs and are not real time. In this work, a real time solid waste bin monitoring system architecture has been proposed which is based on wireless sensor network (WSN) technology. A simulation model have been designed based on the proposed architecture and simulation have been done using Castalia.

Physical architecture:

The hardware architecture of the proposed system is designed in three tier such as, i) lower tier, ii) middle tier and iii) upper tier as shown in Figure 1.

Lower tier:

The lower tier contains the smart bins which are composed with sensor node mounted on it for the data collection and transmission. The sensors are divided into two groups. One group is mounted with the bin cover consists of a magnetic proximity sensor, an ultrasound, load cell, a temperature sensor and a humidity sensor. The other group which is mounted on the bottom of the bin consists of the load cell sensor. The data measured by the sensors are send to the gateway through ZigBee-Pro communication.

Corresponding Author: Md. Abdulla Al Mamun, Department of Electrical, Electronic and Systems Engineering, Faculty of Engineering & Build Environment, Universiti Kebangsaan Malaysia, 43600 UKM, Bangi, Selangor, Malaysia.
Tel: +60149381801, E-mail: md.abdulla@siswa.ukm.edu.my

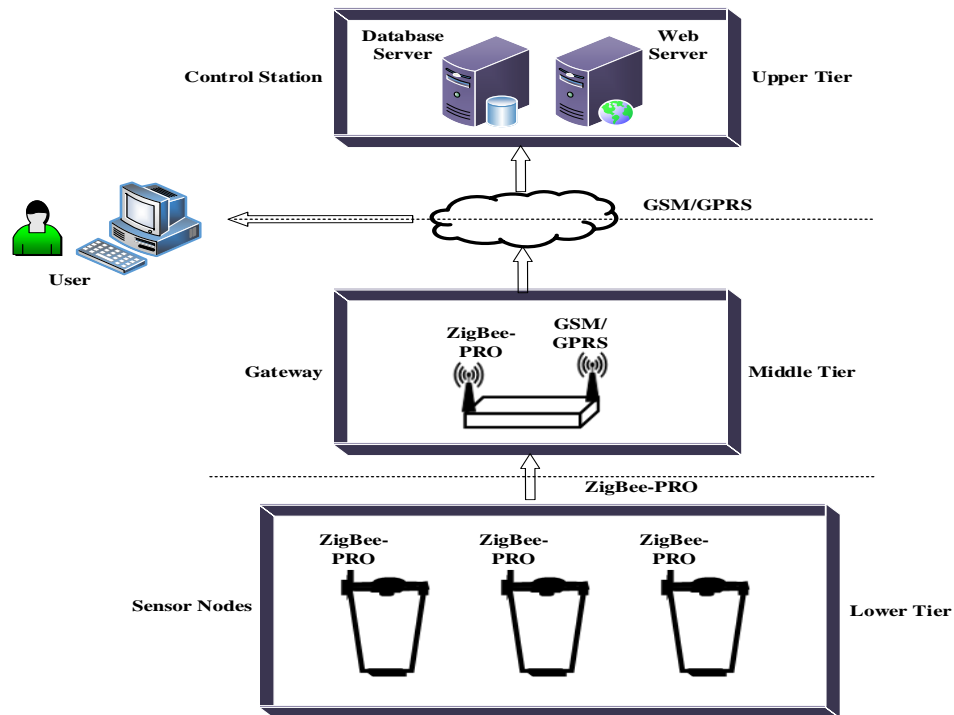


Fig. 1: Architecture of the real time bin monitoring system

Middle tier:

The middle tier consists of the gateways that receive the data sent by the smart bins. It then temporarily store the data while forward it to the control station through GPRS communication.

Upper tier:

The upper tier contains the control station. The GPRS receiver in the control station receives the data sent by the gateway and store it into a central database. The station hosts a set of web application for monitoring the bins status by the user.

Simulation:

To validate and evaluate the working of the proposed system, OMNET++ based Castalia simulator is used. Though currently there are many wireless sensor network simulator available but Castalia provides realistic and modular environment for radio and channel model (Boulis, 2009). Although it has incapability in testing specific sensor node platform, its modularity have significant advantage which facilitates defining each network layer properly and independent of other sensor network layers (Rastegarnia, 2011). Also Castalia is open source simulator so researcher may also implement their own algorithms and applications and can validate it.

Simulation Model and Topology:

The simulation model is as shown in Figure 2 (a) and (b) (Boulis, A., 2009). Each node is defined as a composite module consisting of Radio, MAC, Routing, Application, Sensor manager, Mobility and resource manager modules. The definition of protocols and parameters in each module is necessary and has significant affects in the simulation results.

Using Castalia simulator, a sensor network application is created for the validation of the bin status monitoring phenomenon. The flowchart of the application module is shown in Figure 3. The application trigger the physical process of the sensor nodes after a random time. Then the physical process returns with sensor data sample through sensor manager. The sample is feed into the node's internal processor and some comparison performed. Based on the result of the comparison the sampled data is send to the network layer which place the data to the radio for the purpose to send the data to the sink node. So, the duty of sensor nodes is to report the status of the bin to a sink node. The simulation is performed using star topology. The sink node is placed in the center and the other sensor nodes are deployed in a field using a random uniform distribution.

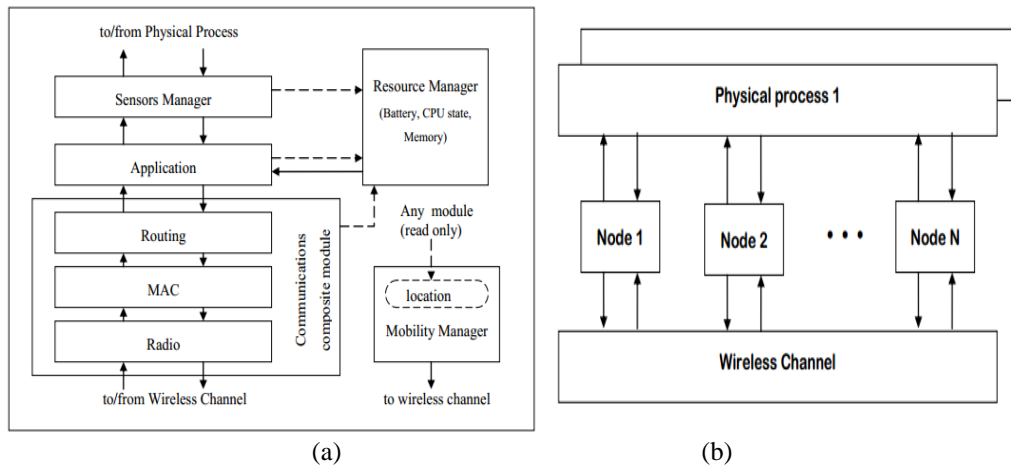


Fig. 2: (a) Composite Node model, (b) Network model

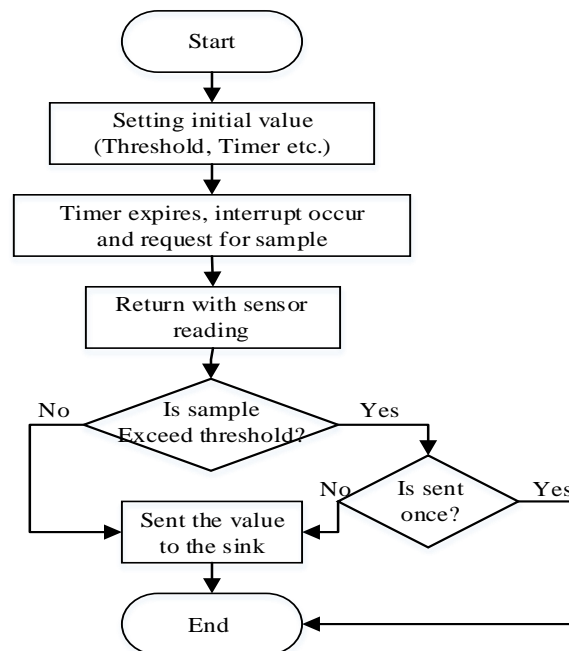


Fig. 3: Flow chart of Application simple module

Path Loss Modeling and Simulation Parameter:

In this system, as the separation of nodes is from a couple of meters to hundred meters, the Log-normal shadowing model has been shown to give accurate estimates for average path loss [11]. This is the formula that returns path loss in dB as a function of the distance between two nodes and a few parameters.

$$PL(d) = PL(d_0) + 10\eta \log\left(\frac{d}{d_0}\right) + X_\sigma \quad (1)$$

where $PL(d)$ is the path loss at distance d , $PL(d_0)$ is the known path loss at a reference distance d_0 , η is the path loss exponent, and X_σ is a Gaussian zero-mean random variable with standard deviation σ .

The metrics and parameters used for simulation are listed in the Table I.

Table I: Simulation parameters.

Simulation parameters	Value
Simulation Time	200s
Simulation field	250×250
MAC protocol	T-MAC
Routing protocol	No Routing
Sensor deployment	Uniform

Packet rate	250kbps
Maximum MAC frame size	2500
Modulation type	PSK
Radio bandwidth	20 MHz
Path loss exponent	2.4
Physical Process	Direct Node Value Assignment

RESULT AND DISCUSSIONS

For the simulation a physical process is created that represents the sensor reading. The physical process contains 10 sample for the ultrasonic sensor that measure waste filling level inside the bin. In a 500×500 meter area 10 bins are considered. The simulation result is shown in Figure 4 and Figure 5 considering a level threshold of 15.

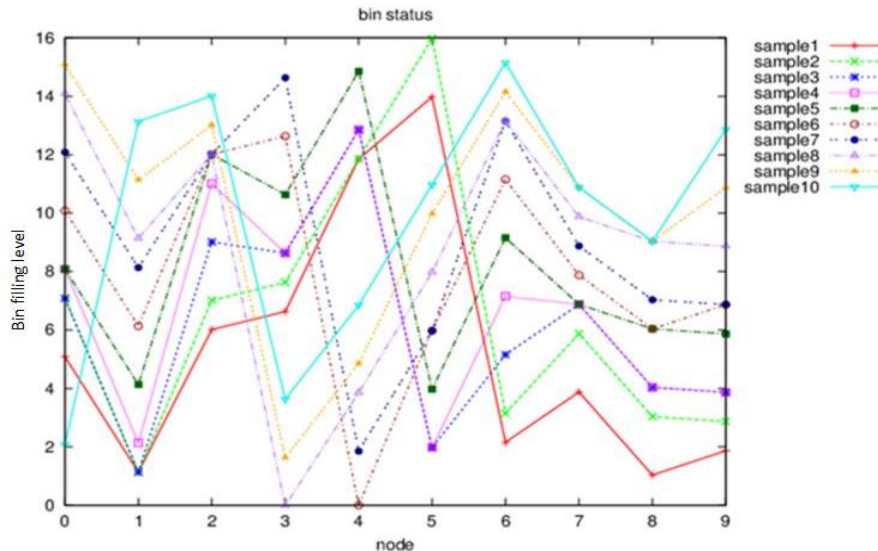


Fig. 4: Node by node presentation of filling level for 10 bins in 10 samples

For Figure 4, the X axis represents the nodes which are equivalent for each bin. Each line denotes a sample that shows the change in bin filling level node by node shown in Y axis. For Figure 5, the X axis represents the sample for each bin which are represent as node. Each line denotes the change in bin filling level sample by sample shown in Y axis. In each sample the filling level is increased and shows a rising trend in the graph. But, for a bin, when the filling level reached in the threshold value of 15 then the filling level value is dropped for the next sample of the corresponding bin. This means that, when the bin is fill up by waste, the system would be updated its information in the control station and the personnel responsible for collection have collected and emptied the bin. The simulation results shows the updated bin filling level with every sample.

Conclusion:

The objective of this research is to propose an architecture for real time bin status monitoring system and validate it through simulation. The designed architecture presents an advance system that can collect and monitor bin information as soon as someone throw waste inside a bin. The tasks are to acquire various data about bin condition, make some initial measurement on bin level and then send the data to the control station through the gateway. The information can further be used to help the route optimization application by providing the collected data in advance. Thus, the proposed system is able to reduce pollutant emissions and operation costs.

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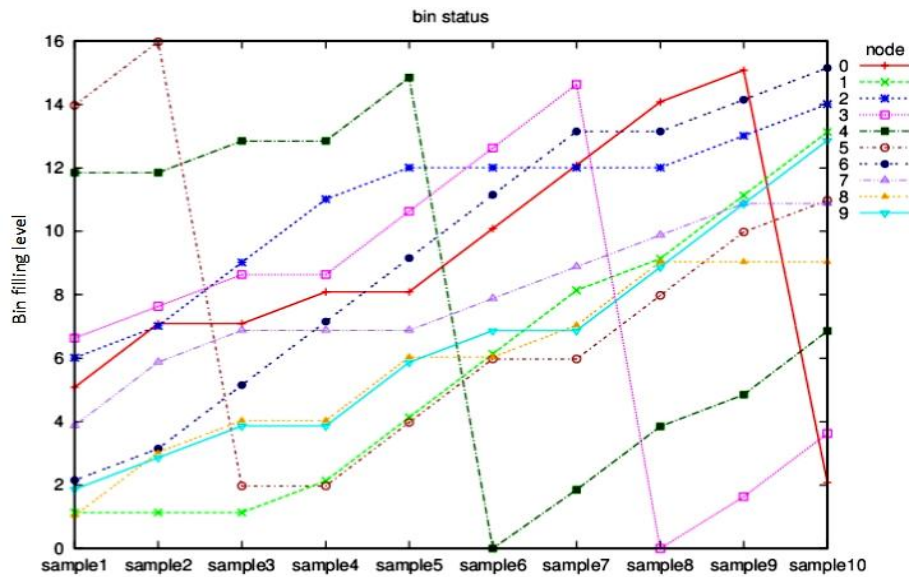


Fig. 5: Sample by sample presentation of filling level for 10 bins in 10 samples

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