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Smartbin: Smart Waste Management System

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***Abstract*—In this paper, we present the Smartbin system that identifies fullness of litter bin. The system is designed to collect data and to deliver the data through wireless mesh network. The system also employs duty cycle technique to reduce power consumption and to maximize operational time. The Smartbin system was tested in an outdoor environment. Through the testbed, we collected data and applied sense-making methods to obtain litter bin utilization and litter bin daily seasonality information. With such information, litter bin providers and cleaning contractors are able to make better decision to increase productivity.**

Keywords—Smart waste, smart cities, wireless sensor network, duty cycle

I. INTRODUCTION

Traditionally, litter bins are emptied at certain intervals by cleaners. This method has several drawbacks such as: (1) some litter bins fill up much faster than the rate of emptying and they are full before the next scheduled time for collection. This leads to overflowing of rubbish bin and poses hygiene risks. (2) There are special periods (e.g. festivals, weekends, and public holidays) when certain litter bins fill up very quickly and there is a need for increased collection intervals. It is a challenge to maintain a clean city. It involves several factors such as different stakeholders, financial/economical, collection & transport, etc [1][2].

The work proposed in this paper illustrates how the Smartbin solution empowers cleaning operators to detect cleanliness issues in real time. Thus, the system is able to help in increasing overall productivity and cleanliness.

II. SYSTEM DESIGN AND TEST BED

Fig. 1 shows the architecture of the Smartbin system. It has a three-tier architecture: (1) outdoor nodes, (2) analytics, and (3) workstation.

A. Outdoor

The outdoor nodes consist of (1) sensor nodes and (2) gateway nodes. A sensor node is installed in every Smartbin. It is powered by a battery. It senses bin fullness and report readings and sensor statuses. The bin capacity is measured using ultrasound sensor. Upon receiving sensor reading, the data is transmitted to the gateway node using low power radio (2.4 GHz band).

A gateway node is installed in every sensor cluster. It serves the sensors under its cluster. The size of cluster is determined by outdoor range and density of Smartbins. Upon receiving sensor data from the sensor nodes, it forwards the information to the backend server via any internet connection (e.g. Ethernet, WiFi or 3G connection). In our setup, the gateway nodes are mains-powered.

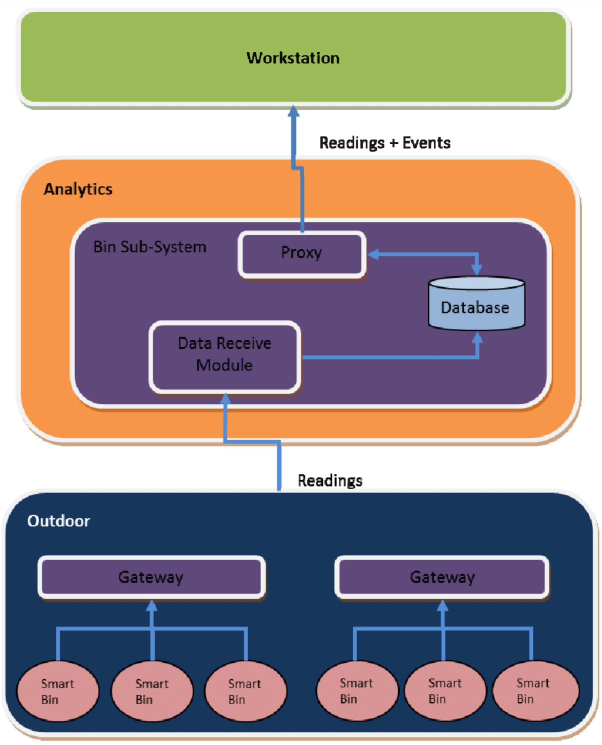

Fig. 1. Smartbin system architecture

B. Analytics

At the backend server, the analytics module analyzes data collected by the bin sub system. The bin sub-system collates and processes data, tags metadata, and interfaces with external systems. The analytics module processes fullness readings, compares against predefined rules, and generates event upon exceeding threshold.

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C. *Workstation*

The bin sub-system pushes information to the workstation. The workstation then shows meaningful information to users through a graphical user interface. Each bin will be visualized using an icon on a GIS (Geographic Information System) [3] map on the operator terminal. The bin fullness level will also be visually displayed on the operator terminal.

A total of eleven Smartbins and two gateways were deployed in the testbed. They were deployed in two different areas. On one area, there were seven Smartbins being deployed. For this area, the maximum distance between the Smartbin and the gateway was around 240 meters. On the other area, there were four Smartbins. The maximum distance between the Smartbin and the gateway in this area was around 110 meters. The sensor node sensed the bin fullness every five minutes and sent the information to the gateway. To conserve battery and to maximize the operational time of the system, a duty cycle method was employed. When the sensor node was not sensing (i.e. idle mode), it went into the sleep mode.

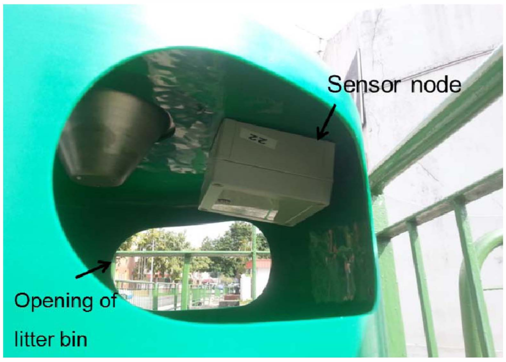

Fig. 2. Sensor node deployment inside litter bin

Upon receiving the information from sensor nodes, the gateway forwarded the data to the backend server for further data processing. The sensor node was also equipped with a Global Positioning System (GPS) to obtain location information. With location information, the system was able to track current location where the Smartbin was deployed. To transmit the collected information between the sensor node to the gateway, both devices were equipped with low power 802.15.4 wireless radio [4]. To extend the network coverage of the Smartbin solution, wireless mesh network [5] was implemented at the sensor node. Thus, it enabled the Smartbin solution to have self-forming and self-healing network capabilities. The sensor nodes were deployed in harsh environment. They had to sustain dust and water splash. Therefore all the sensor nodes were enclosed in IP65 rated casing (see Fig. 2).

III. Practical Challenges

Before the deployment of Smartbins, a site survey was carried out. The objective of the site survey was to measure the maximum distance and the quality of radio transmission between two radios. The site survey was carried out by using two nodes: transmitter node and receiver node. A sensor node was used as the transmitter node. A laptop was used as the receiver node. The receiver node stored received packets and calculated Packet Delivery Ratio (PDR) and Received Signal Strength Indication (RSSI).

The wireless communication module attached to the sensor node was low power and low bandwidth (250 Kbps). With its limited bandwidth, a technique was applied to compress sensor information and, at the same time, data repetition was also included to increase data reliability.

The sensor node was deployed with battery power. Due to its limited power, a low power consumption sensor node was selected. The sensor node had limited memory size. This had an effect on the size of the program running on the sensor node. Thus a simple opportunistic routing protocol was chosen as the routing protocol.

IV. Results

We had collected six months of data during the testbed period. Based on the information collected, the average data delivery ratio is 99.25%. The data was also analyzed to obtain litter bin utilization and litter bin daily seasonality information. The litter bin utilization information shows how a bin has been utilized. The litter bin daily seasonality information shows the time when a bin is usually full.

V. Conclusion

The Smartbin system was implemented and deployed on outdoor testbed. It incorporates mesh network and duty cycle features. From the litter bin utilization information, litter bin providers are able to identify and decide whether a particular area needs extra litter bins to be placed nearby or remove/relocate existing litter bins to other places where they are needed. From the litter bin daily seasonality information, cleaning operators are able to better plan when they should send their cleaners to empty the bins, and they are also able to plan which routes their cleaners need to take.

References

[1] Guerrero, L.A., Ger, G and William, H, "Solid waste management challenges for cities in developing countries," *Waste Management*, 33(1):220-232, January 2013.

[2] Marshall, R.E and Farahbakhsh, K, "Systems approaches to integrated solid waste management in developing countries," *Waste Management*, 33(4): 988-1003, April 2013.

[3] Demers, M.N., "Fundamentals of geographic information systems," *Wiley*, March 2009

[4] IEEE standard for local and metropolitan area networks part 15.4: Low-rate wireless personal area networks (LR-WPANs), September 2011.

[5] Akyildiz, I., and Wang, X., "A survey on wireless mesh networks," *IEEE Communications Magazine*, 43(9):S23-S30, September 2005.

[6] "Smartbin video," https://www.dropbox.com/s/ywcna863iil1uuy/SnS-Smartbins.mp4?dl=