IoT Based Smart Solution for Waste Collection and Recycle

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Abstract — *Solid waste generation has become a dreadful challenge for municipal councils of Sri Lanka. Increase in the Population, Urbanization, and Tourism are some of the major causes for this enormous increase in waste, although many companies and individuals make a fortune by systematically recycling those waste. At present many of the organizations who have a keen interest on those wastes such as plastics, steel and paper, usually collect those raw materials form municipal councils, or from "bottles, plastic, steel paper collectors" for a price and it facilitates an eco-friendly practise in those organizations when they produce a product using those recycled waste. As of today, with internet of things (IoT) and relevant other technologies, it makes it easier to develop a smart and efficient waste collection and recycling system. The authors presenting an Internet of things-based solution to overcome these challenges the society face due to solid wastes. This system will enable a convenient access to organizations who uses recycled solid wastes in their production processes. Users will be monetarily benefited with every transaction. Meanwhile companies will lower their costs. An online survey was distributed via emails and it was successfully completed. As per the survey analysis, organizations, municipal councils and public shows a greater satisfaction for the proposed system. Satisfaction towards the prevailing system is not much acceptable. The authors have designed the architecture, a smart bin and the design for Internet of things based smart waste collection and recycling system.*

Keywords*: Internet of things, Recycling, Solid waste.*

I. INTRODUCTION

Solid wastes which remains in cities has become a very challenging and hazardous to every nation. Not only cities, places such as logons, oceans and rivers are also polluted by wastes in different forms. Cities with a lot of economic activities or tourist activities faces this issue in much worst scale. Sri Lanka collect around 3000 metric tons of wastes daily and more than 100 local authorities have been funded with technology and in financial aspects to implement a recycling program for the whole nation.

Wastes such as plastic, steel and paper can be recycled and reuse. And many companies will be benefited as a result, along with other individuals. Mass scale producers uses recycled raw materials for their production processes. to get those wastes as their raw materials they must bulk purchase those waste materials from municipal councils or other individuals.

Therefore, to cope up with the above issue authors have developed a smart waste collection and recycling system for household-based waste management using Internet of Things. The research project BinGO is an efficient waste collection and recycling management system, which is developed using smart bins, Web application for the administrators and the mobile application for local users, organizations and truck drivers.

The BinGO is designed to receive and transmit real-time data regarding smart bin's statuses to the main server. Such data will be used to address the requirements of domestic authorities and users. unique features such as garbage collection, scheduling pickups, real time monitoring, Information and data maintenance and reports have been enabled with centralized web application. Further the mobile application will enable the users to use cost effective collecting routes, get bin status notifications, pickup schedules, and request for an immediate collection as soon as possible. The application will reward the users systematically along with the system's terms and conditions. Suggested research project BinGO will ultimately minimize the issues regarding the waste management and enhance the recycling of wastes, also the system provides a user-friendly application for centralized management overall.

II. LITERATURE REVIEW

In this century people are much more involved with the advanced technologies and usually do all their tasks by applications. with regards to that, the concept of IoT is now a famous topic and it facilitates many of the problems faced by humans. Many projects have been done regarding garbage management for last few years with these technologies and internet of things.

Study of the research done by M. Pankaj Morajkar (2015) has used to get the fill level of the garbage whereas GSM modules have been used to transfer required data to control room. The Arduino microcontroller interfaces between the sensor systems and GSM module. Overall monitoring and maintenance of garbage related information have been achieved through user-friendly interfaces. A unique ID has been provided for each garbage bin available in the city so that it was easy to identify which garbage bin is full. When the garbage level reaches the limit, the device had transmitted the level

along with the unique ID provided. These details will be then accessed by the authorities from their place through Internet and an immediate action will be made to clean the dustbins. Benefits of this system are cost reduction and resource optimization, intelligent management of the services in the city and effective use of dustbins. In research "IoT Based Waste Management for Smart City (2016)" they have used the same technologies and the methods used by M. Pankaj Morajkar to solve this problem. It was a success but the notifications to the user regarding collections were not notified and system was implemented without any feedbacks or user interference like proposed in the system which is proposed.

Then, P. D Nalamwar (2016), Mahesh N. Jivani (2016) proposed an integrated system which is combined with an integrated system of ZigBee and Global System for Mobile Communication (GSM). Garbage bins in public places have been targeted in its research. When the garbage reaches the level of the sensor, then that indication had given to ARM 7 Controller. The controller will then notify the driver of garbage collection truck to get immediate attention. ARM 7 used GSM technology to send out the SMS to the driver. ZigBee technology for garbage bin detail and real time monitoring of garbage bins and information transfer, resource optimization and truck monitoring system used GSM. But the systems couldn't get real time data to the backend and MQTT client will be much more convenient when passing real-time data machine to machine in today's technological advancements in IoT.

Ms. B.M. Mamilwar came up with a research article on Door to door garbage collection. Here research has been made to ensure zero garbage level with services at minimum cost. ARM 7 controller was sending short message service to the cleaner to clean the dustbin. When dustbin was filled then, SMS sent to cleaner by using Global System for Mobile, but the system is not much accurate and user-friendly and it no proper routes or user interference to the system smoothly.

S. J. Dawada, K. Mahajan, and K. Maurya found another solution using RFID and GSM for Garbage Collection. Systems developed and contributed to reduce the pollution in the city, stop many health problems for the households and reduce the fuel consumption of the collection trucks. The locations of the trash bins also could be identified easily by those systems. Yet the fastest routes or economical routes weren't analyzed by the system. "Smart Vehicle Tracking System" research found a method to calculate the distance traveled two stations with web application via Google map. Use OF GPS-GSM based tracking system along with Google maps. Then message transmission time and position were at that time. These systems should have a service provider contract. Another automated smart garbage collection technique has been suggested using Image processing and GSM for data transfer. When garbage filled then cleaner can collect the garbage. These systems can reduce the productivity of the vehicles and manpower. Those didn't mention the following features, need electricity anytime and these systems can only see the garbage fill level and weight. Then, identified that garbage removal and management of removable garbage were performed the main role to improve the health of the people. The system doesn't have any method to notify the user when trucks are around.

E. Abbott and D. Powell came up with managing the waste collection system of an entire city. The project gave one of the most efficient ways to keep our environment clean and green. Research brought clarification about the waste management in urban areas and it targeted at encouraging further research on the topic of waste management.

N. Kumar in 2014 found a solution which dispose of the waste with Wireless Sensor Networks (WSN) using VANETs. It was the easy way for long distance communication without GSM module as well as the driver could easily understand where garbage was filled. Methodologies such as Vehicular Ad-Hoc Networks (VANETs) was used to provide communication between the vehicles. Then sensors were used to estimate the filled level, but the system may sometimes be vulnerable and real time data collection might have been delayed. The system doesn't give access to the user to request for an immediate vehicle

After studying those previous researches and projects, Cleary shows that none of them had included a method for a general citizen to involve in collecting waste and have rewards and no cross platform mobile application developed by any developer or suggested by authors. None of the systems were able to include a feedback, Rate, complain the system/Truck driver. Therefore, eventhough there are many projects being done regarding this waste managing problem. Those solutions were not be able to solve it completely. Since only the municipal councils have the incentive to do it. But in the system the author proposing Households and the municipal council garbage collector will be motivated to get involved and be rewarded by the system, because it includes a business revenue model for the users and it promotes green environment and clean city. With the aid of IoT Linkit One board rather than Arduino mega board and most advanced technologies such as MQTT Client, Firebase databases and applications made form React native which passes real time data to the backend and the frontend of the system. The system supports both IOS and Android.

III.OBJECTIVE OF STUDY

Minimize the issues related to waste management and promote recycling and reuse by providing user-friendly applications to users and with the implantation of Smart garbage bins for effective monitoring and collection of solid waste matter.

IV.OVERVIEW OF METHODOLOGY

The authors formed a hypothesis which was designed by the responses collected from the survey. The authors analysed the responses and checked the correspondence between the responses and the hypothesis which was developed earlier in the process, thereby proposing a smart waste collection and recycling system.

The survey was carried out using with the involvement of a Negombo municipal council, set of "bottles, paper, and metal collectors, random citizen and a famous company which uses recycled wastes for production as inputs.

V. METHODOLOGY

Section V discusses about the phases of prototype methodology which is used for the initial development of The BinGO system. And, the procedures in every phase and materials produced in those phases of system development Lifecycle (SDLC).

A. Planning

Initial planning for effective development of The BinGO system was initiated in this phase. Authors comprehended the need for The BinGO system after studying traditional waste collection system and the ways of recycling. Work Breakdown Structure (WBS) and Gantt chart were modeled to determine the way of developing this system. finally, a feasibility study which includes economic, technical and organizational was carried out to determine the feasibility of the proposed system.

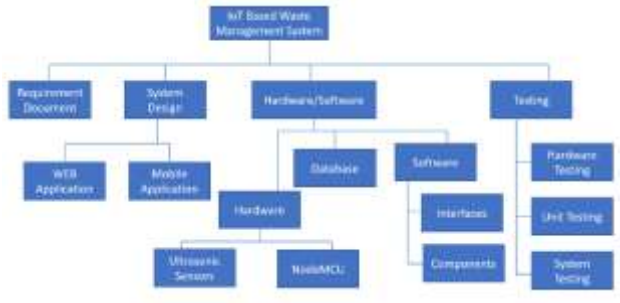


Figure 1: Work Breakdown Structure of BinGO system
Source: Author

B. Requirement Gathering and Analysis

Requirements were collected as both primary and secondary data for the basic analysis and to identify what are the similar projects developed in the industry. Questionnaires were used as tools to collect primary data and the Background study (II LITERATURE REVIEW) was used to collect secondary data. Collected information was carefully analyzed to identify the requirements of the users. Some of the important questions from the questionnaire are given below.

a. Are you satisfied with the current waste management practices and recycling procedures?

Most of the answers proved that the current method of waste management is not much satisfying. 80% of the answers reveals that their satisfaction in very low. Therefore, the need of a new effective system is a requirement as per the authors conclusion.

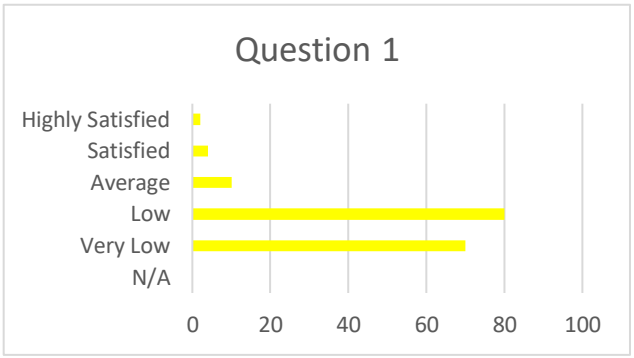


Figure 2: Analyzed Data Chart
Source: Author

b. Are you aware of how wastes are being recycled?

Most of the answers were in the region of Average. Which is 50% And the awareness of recycling procedures is not much known by the society, since they don't involve in the process directly. Therefore, this system will make aware the society about the recycling methods and ultimately promote ecofriendly nation.

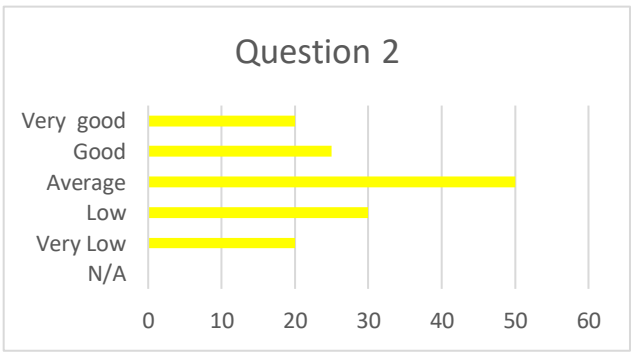


Figure 3: Analyzed Data Chart
Source: Author

c. How is your knowledge on mobile applications?

In this century most of the citizen are using mobile devices and have a better knowledge than ever before. As per the analytics the knowledge and usability of mobile devices are showing very good feedback of 70%. Therefore, authors are very much happy to provide a mobile application for the users to get involved with the system.

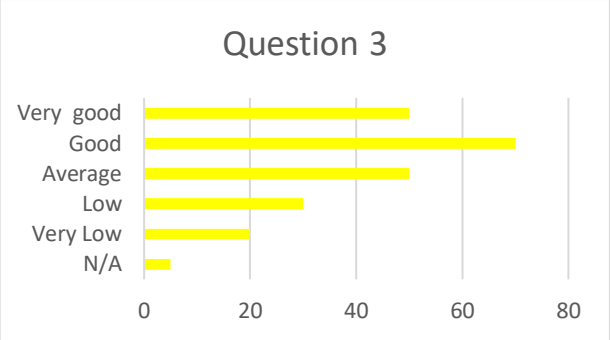


Figure 4: Analyzed Data Chart
Source: Author

d. Will you be satisfied if the waste management and relying process is automated and provided as a mobile application to be used?

Most of the answer were in favor of implementing this system, which is 90% and the actual requirement of the waste collection and recycling system is emerged here, and the authors will develop the proposed system to overcome those challengers.

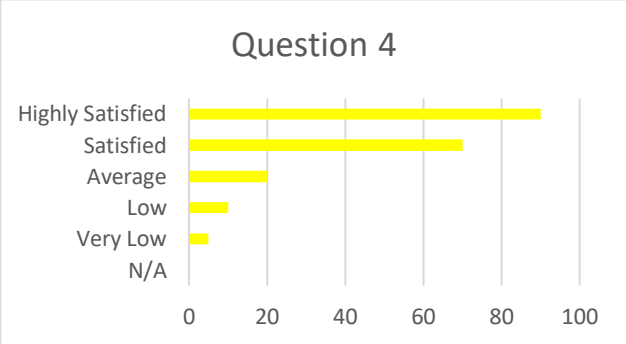
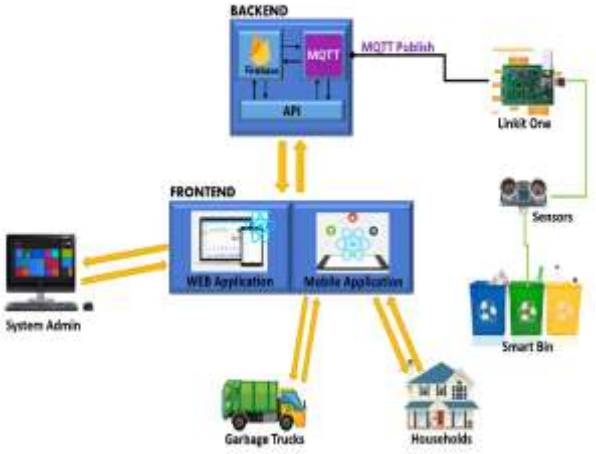


Figure 5: Analyzed Data Chart
Source: Author

C. *Design*

Initial basic system architecture design for The BinGO system was sketched to have good idea about the exact operations required to be performed in developing. Architecture diagram, Hardware infrastructure diagram of Smart bins, and Interface designs of both web application and cross platform mobile application were sketched. Decisions were made on hardware programming IDE, Mobile development kit, Web application platform and Database servers to be used in the system. Figure 6 depicts



the system architecture diagram of BinGO system.

Figure 6: System Architecture Diagram
Source: Author

In this IoT based waste collection and recycling system, Real time data from smart garbage bins or the bin status data will be transferred to the backend of the system form Linkit one board through MQTT publish (MQTT Client) and then then data will be stored to the database of the system (Firebase Database). Also, at the same time data will be passed to the frontend (Web Application and Mobile Application) of the system through an API. Web application can be monitored by the system administrator (Municipal Council) and the Mobile Application can be used by the garbage collecting trucks and the Households to engage in an efficient waste disposal. Requests, Feedbacks made by the households and Truck collectors will be sent back to the system through the frontend (Web Application and Mobile Application), and the system admin can monitor, response to them on demand. when a user (household) needs an immediate waste disposal, request will notify the truck drivers. At the end of the day System administrator can generate summarized reposts.

D. *Implementation*

Hardware assembling, and coding were initiated to develop the output of design phase. Load cell sensors, Ultrasonic sensor are connected to Linkit One board, the advantage of using Linkit One board is it comes with built in GPS module and GSM/GPRS Shield. Then the hardware is fixed to the smart waste bins. During hardware

assembling process. MQTT client will be used to receive and transmit required real time data from the smart bin to the backend. Cross platform Mobile Application, Web Application, and Web Service will be developed in parallel using React and React Native technologies respectively. Firebase server to be used with Firebase Cloud Messaging (FCM) notification service to send necessary notifications to the Mobile Application. C#.NET, and Java were used as programming languages. Application Programming Interface (API) with restful services has been used to manipulate database contents. Also, user-friendly interfaces for the easy use of the proposed system.

E. Testing

In this phase The BinGO System was tested by applying different effective Test cases. Test cases were prepared to test every path available in the codes of Arduino microcontroller, Web application, and Mobile application. Unit testing, Integration testing, Regression testing and System testing were passed out to ensure the system's reliability and efficiency. Different units of The BinGO System were tested separately in unit testing and since React technologies are used to build the web application it is very much easier, whereas Integration of all the units be tested during Integration testing and System testing.

VI. RESULTS AND DISCUSSIONS

Section VI discuss about the results of the proposed waste collection and recycling system. The BinGO System contains three major components. Smart Waste Bin, Web application for the use of municipal councils and Organizations who uses recycling wastes and the Mobile application for collection vehicle drivers and smart bin users.

Mainly, The BinGO smart waste bin is developed to read and transmit plastic, steel, or paper level details such as height level and weight of collected wastes. Location of waste bins will also be read and transmitted to the main Server. Figure 7 below shows a prototype design of smart waste bin.

Figure 7: Proposed Smart Bin
Source: School of Electrical and Electronics Engineering, Chung-Ang University, Seoul 151-756, Republic of Korea

The smart bin level readings and related details received from smart bins were transferred to the main web application of municipal council or the Client Organization to ensure proper waste management system. These bin statuses are displayed in smart bin user's mobile application too. The user has the privilege to request for an immediate pick up eventhough the bins are not fully filled. Such kind of pickup may cost the bin user according to the terms and conditions of the business model of either municipal council's or the relevant organization. Figure 8 shows the Mobile application interface of the bin status details.

Figure 8: Mobile Application Bin Status.
Source: Author

At first, Municipal council authority or Organizations registers Customers (households), Collection vehicle drivers, Trucks, Recycling companies, Collection areas, Collection routes, and Smart waste bins. Figure 9 below shows the proposed Web application interface.

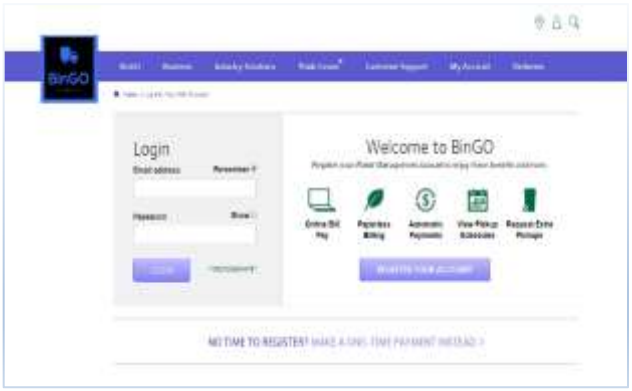


Figure 9: Web Application Home Page

Source: Author

Real-time monitoring regarding waste collections is attained through Google map API, embedded in the main web application. The easiness of finding the type of waste

is easy for the user because of this monitoring method. Figure 10 below shows the Web applications Realtime monitoring interface.

Figure 10: Web Application Monitoring Page
Source: Author

Cost-effective real-time navigation routes for collection areas and immediate pick up requests are displayed to the truck drivers using BinGO cross platform mobile application. Figure 11 below show the Navigation interface for the Truck drivers.

Figure 11: Mobile Application Monitoring Page
Source: Author

VII. CONCLUSION

With the increments of economic and tourist activities in cities, and because of Urbanization and Industrialization cities create tons of solid wastes daily. It has become a challenge to the entire world. Research project BinGO provides wide-range of solutions with its unique features and interesting revenue models to face those challenges effectively by smart waste collecting and recycling. The BinGO system can read and transmit real-time statuses of waste bins to the system servers. And the truck drivers (waste collectors) provided with a mobile application to assist them. Notifying the domestic users about the pickup schedules and the domestic users have given the privilege to request for an immediate pickup under a payment involvement. Required reports can be generated from the system on demand. Further real time monitoring of waste collection, scheduling pickups and route generating are also done by this system. Finally, the proposed project successfully achieved the objectives and became a success in aiding domestic individuals, municipal councils and other organizations. authors believe that this study will be valuable for anyone who's interested in this field of research and hopes this research project will benefit in implementation if similar kind of projects with more advanced and hi-technical tools.

VIII. FURTHER WORK

Since this project was a massive one with many aspects to be covered, authors limited few of the mandatory requirements during the development of this project, and those limitations must be considered as the vitals in next approach. such limitations are mentioned below:

A. Zero error policy with the implementation of metal detectors.

Wastes are categorized into categories, Such as plastic, metal, and paper. If by mistaken or deliberately metal was put into plastic, the system must be able to detect it and notify the user. The same should happen if it happens vice versa.

B. Solar power for automatic battery charging.

The battery should be recharged in regular intervals for a reliable functioning of Smart bins. Therefore, upgrading the circuit with automatic solar power charging will be the immediate next step of this project.

C. More effective Business model.

Revenue model implemented to motivate domestic and casual users of the system is not much effective. Therefore, reengineering business models and processes to have a competitive and promoted application.

D. Accessibly features to get the involvement of all the users.

Applications were developed for the use of physically abled persons only. Upgrading the application with accessibility features will benefit everyone who uses it.

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