A Review Paper on Robust Waste Collection: Exploiting IoT Potentiality in Smart Cities

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Abstract- Civil habitation is moving fast towards the urban civilization. Everything is heading towards digitization and automation. Internet of things (IoT) is the latest innovative approach known for its automation facilities. The cities are incorporating IoT in their backbone infrastructure to become smart cities. Amongst numerous applications of IoT, waste collection is one of the most useful one. Waste generated from various sources such as household, industries, hospitals, construction sites etc are in large amount. All these solid waste possess a great deal of concern worldwide. Although waste collection methods in the past years have been static, it is essential to develop an automated system. This is important for reducing manual work and time consumption. Waste collection via IoT can provide an innovative and robust approach. This paper provides a method for waste collection in smart cities incorporating IoT. The city is considered to be divided into number of sectors, each including certain areas and bins. This method uses smart bins that notify when it is to be emptied. This is done by including certain hardware in the bins. It can also handle vehicle malfunction. The server is informed when a vehicle is malfunctioned and its services are allotted to another vehicle. Also a ward member for every sector is allotted who is also notified with the status of the bin.

Keywords- *Internet of things, waste management, automation, smart city*

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I. INTRODUCTION

Internet and its growing applications have become an important part of human lifestyle. As a result of these growing necessities, application of internet went way beyond connecting just the computers to web. One such application is the development of the concept of Internet of things. IoT refers to connection of physical devices to the internet such that they can be automated. These physical devices could be anything such as hardware, software, data or a service. This may include vehicles, buildings etc. IoT is that development which changed the user- user communication to device – device communication.

Smart city is the city that integrates various technologies and Internet of things to provide different services of a city [3]. These services may include administration, healthcare, education, transportation, agriculture etc. The necessity of building smart cities is to enhance the quality of living and the services provided to people. IoT is the need of the future worldwide. It has a wide scope in the near future in every field [1]. One of the fundamental components of smart city is smart environment. Its essential service is the smart waste management. Incorporation of technologies such as IoT transforms the cities into smart cities [2].

Growing waste is a major problem to deal with in today's era. Actions must be taken to develop proper waste management system. In the past years waste management was treated as a static service. Door to door waste collection was a prominent way of waste collection. But with the high technological developments it is not an efficient approach. Innovative approach is a need for today. IoT provides one such approach in building a real time and automated system. Internet of things interconnects various objects such that they can exchange data. These things include a wide variety of devices such as vehicles, buildings etc. It could be anything in hardware, software, data or a service. The network connectivity it provides makes it more usable. In the near future everything would become smart i.e. incorporated with IoT. One major concern in waste management is vehicle routing. Directing the vehicles to correct route is necessary. Shortest routes must be chosen always. This will lead to less fuel and time consumption.

This paper provides an innovative approach for waste management. It will help to develop a real time and automated system. City is divided into many sectors. Each sector is incorporated with certain number of smart bins. These bins are included with hardware which consists of micro controller, GSM, and sensors. Micro controller is kind of a mini computer that handles the functioning of system. The sensors will sense the level up to which the bin is filled. Upon completion it will give a notification to the server. The server will route the vehicle to the bin for emptying it. The vehicle will carry the waste to the dumping area. In case of any damage caused to the vehicle, a new vehicle will be routed to that bin.

II. RELATED WORK

Various static as well as dynamic models have been developed for waste management. Although static models cannot handle the dynamic nature of IoT, so most models handle waste collection problem dynamically. This section contains work related to the dynamic approaches.

W. Juyoung et.al [4] proposed a method based on roll on – roll off routing. This approach was suitable for the places that generated huge amount of waste. Such places often could be industrial areas, construction sites, shopping districts etc. The container size differentiated whether to use roll on or roll off routing. Pickup and transportation were the major concerns in this method. Also unloading the large containers, mainly at construction sites was a problem. Another method was based on ant colony system (ACS) algorithm, presented by M. Reed et.al [5]. The ACS is based on probabilistic models and helps achieving dynamic routing. In this approach the spatial location of bins is considered. K-mean clustering is applied to form partial clusters. It takes into consideration the behaviour of real ants. It also keeps a record of the past actions performed.

K. Buhrkal, A. Larsen [6] proposed a method that used routing with time windows which analyze the logistics activity within a city. The time windows applies a restriction on the vehicle arrival time which must reach before the window expires. This restriction leads to imposing complexity in the system. This method works towards finding the optimal route for a vehicle such that the waste is emptied into dumping area within the time window provided. X. Bing [7] presented a model which separates the degradable and non degradable waste. It removes plastic waste from other solid waste. It is a specialized approach that uses eco- efficiency as an important metric. Eco-efficiency deals with the social issues, costs, environmental impacts etc. This method considers studying of number of scenario based on various assumptions in collection methods, collection points, vehicle type etc.

M. Mes [8] proposed a different approach for the waste collection from underground bins. Motion sensors are embedded in the underground bins which transmit information required for dynamic planning. A drawback of this system is that, even though motion sensors are present the routing is based on static schedules. To achieve dynamic planning, sensor information must be used appropriately. This would lead to a more efficient system in terms of cost, profit and time. Another heuristic solution is devised by Vera Hemmelmayr et.al [9] where authors state the waste collection as a periodic truck routing problem with intermediate 2 waste depots. Using this system, all kinds if waste i.e. glass, paper, plastic etc are collected and bought to a certain point by the citizens. Therefore, this collection is treated as a node routing problem. This waste is then taken to special sites called intermediate facilities (IF). These are similar to depots. Thus, this approach requires a planning period of certain days because every collection point need not be visited every day.

Hui Han and Eva Ponce [10] studied the waste collection vehicle routing problem (WCVRP). It studies waste collection of three types of wastes: industrial, commercial and household. This paper consists of various methods proposed by different authors for waste collection of the three categories. Various classical heuristic and Meta heuristic algorithms are studied. Somayeh Fooladi et.al [11] devised a mathematical model for the reduction of cost of collecting and transporting the waste for recycling process. It keeps a balance between distance between trashcans and the type of waste contained in trashcans to find an optimal route for transport vehicles. Designing if similarity pattern is done for this purpose and this pattern is used for selection of route. A mixed-integer non linear programming is applied in this approach. A paper was presented by Aderemi Oluyinka and olawale Adeleke [12] who gave a new approach for waste management using customer's time windows and road attributes. It works in order to reduce the high cost required to manage the garbage carrying vehicles. Its major contribution was the consideration of attributes of each road in collecting solid waste. Two approaches were proposed, one using non- linear function and another using a linear function.

P. Pratheep, M A Hannan [13] proposed the system for monitoring of waste bins carrying solid waste using RFID technology. It stores all the information related to driver, vehicle, and location in the database. This technology is used for handling the transmission and reception of data. Clients can access the database for system information. The recycle bins are incorporated with reader and the trucks with RFID tag. The hardware implementation of this system is very complex and it is suitable only for designing a prototype due to short range of frequency detection. Theodoros Anagnostopoulos, Arkady Zaslavsky et.al [14] proposed a robust waste collection system for smart cities. They considered two types of trash carrying vehicles, high capacity trucks (HCT), and low capacity trucks (LCT). A robust routing algorithm was applied which was common for both the types of vehicles. It could also handle malfunctioning of the trucks. They studied two scenarios for LCT and HCT. First scenario considered carrying the waste from bins directly to dumping are by LCT. Second scenario considered depots as temporary storage, thus carrying waste from bins to depots by LCT and depots to dumping are by HCT. It showed that the use high capacity trucks reduced the operational cost for waste carrying and transportation.

Another method was proposed by *S.S.*Navghane,M.S.Killedar, et.al [15]. The authors presented a model using IR sensors, microcontroller and Wi-

Fi module. This model assures that the bin is emptied as soon as it reaches its maximum capacity. If it is not being emptied then the record is sent to higher authority which can take necessary action. This system also assures that the overall expense required for waste collection is minimized by developing cheaper bins, thus making the system more efficient.

Alexey Medvedev, Peter Fedchenkov et.al [16] proposed a methodology for smart waste collection. Firstly, they worked for providing software-as-a-service (SaaS) product to customers. The customers here are mainly private companies which work for waste collection in cities. Secondly, they worked for developing a system which is beneficial to all the stakeholders involved in the garbage collection process. The important component of their system was cloud based decision support system (DSS), an intercommunication channel. The DSS have all the information related to bin capacity, truck location, fuel available and consumed etc. This provides an easy way to provide optimal route to the customers.

Authors Gaurav Kodwani et.al [17] have presented a paper on an automated alarming system sing a smart container. Major components of this model were: IR sensors, GSM connected to Arduino, and alert via SMS. The IR sensors were used to detect the minimum level required. The wireless GSM modem was used for communication over wireless network. It used SIM card and IMEI number for this purpose. Alert notifications were provided through the message on mobile phones.

Vikrant Bhor, Pankaj Morajkar et.al [18] proposed a smart garbage management system consisting of transmitter and receiver sections. The transmitter section consists of smart bins incorporated with level sensors and microcontrollers. The output of level sensor is provided to microcontroller. At the receiver end is a control room handled by a person who monitors all the activities. A GSM module is used to send a notification for clearing the dustbin. This system also consists of a GUI which displays the level of the dustbin on a computer screen. This system also assures monitoring of the fake reports, thus making it more reliable.

Meghana K C and Dr. K. R. Nataraj [19] presented a method for construction of smart bins using infrared sensors and GSM facility. LED's are present near the bins which emits light when the bin is full. The road maps showing a route to the bins is attached to the internet. On clicking the blinking LED, the road map shows the route to be followed. A text message is sent to the mobile number of the concerned person. All this can be visualized in the control room. This model allows the reduction in the number of times the vehicle must travel to empty the bins. Such smart bins were a great development toward clean environment.

III. PROPOSED SYSTEM

This section presents an innovative robust approach for waste collection in smart cities. This method considers the city to be divided into many numbers of sectors. Each sector consists of some buildings, houses or areas. Numbers of bins are incorporated in different areas. These are called smart bins as they are attached to certain hardware. Trucks are used for carrying garbage to dumping areas. An android application is available for handling the system remotely. This application is used to track the vehicles, know the status of bins, direct the vehicles to proper routes etc. Notifications are provided through this app. The GSM technology is used for the mobile communication. For every area a ward member will be appointed to take care that all the activities are performed on time. When the maximum level of bin will be reached a message will be sent to the ward member for making sure that the bin is emptied. In case of any delays this member must take appropriate actions.

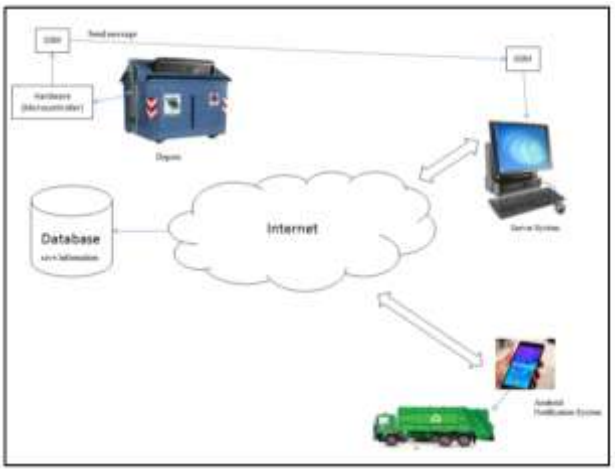

Figure1: Working of IoT enabled waste management system.

The block diagram of the proposed system is as shown in figure 1. Everything is connected over internet. Level sensors are attached to the bins. These sensors in the bin will sense the level up to which it is filled. It will send notifications at different levels of bin being filled. After the notification of bin being filled to its maximum level, it must be emptied immediately. If the bin is not cleared then the alert message will be sent to the ward member appointed to that area. The analog to digital convertor is used to convert the signal of sensors into digital value. Microcontroller controls all this functioning. The RS232 communication is used for communication between hardware and software. After getting a notification about the bin being filled, the system routes a vehicle to empty the bin. Meanwhile, if any malfunction occurs then the server is informed about it.

The proposed system will also assure that the vehicles used to empty the bins are routed to the smallest route. When a vehicle is serving a bin, it will be informed about the nearest bin to be served, if any. Also the system will handle the truck malfunctioning. In such a situation, the server will be notified about the vehicle being malfunctioned. The server will give all the allotments of this vehicle to another working vehicle. Thus, this system will be able to continue working even under the case of malfunctions.

IV. CONCLUSION

Waste collection as treated as a static problem in the past years. These static methods were not compatible with the dynamic nature of IoT. So a dynamic method had to be developed for the smart cities which could also use the potential of IoT efficiently. This paper presents an innovative and dynamic approach for this problem. An android application is also provided to handle the system functioning remotely. This makes the system more usable. This system can also handle vehicle malfunction by allocating its services to another vehicle.

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REFERENCES

[1] Jayavardhana Gubbi, Rajkumar Buyya et.al, “Internet of Things (IoT): A Vision, Architectural Elements, and Future Directions”, Future Generation, Elsevier, 2013.

[2] J. Jin, 1. Gubbi, S. Marusic and M. Palaniswami, "An Information Framework for Creating a Smart City Through Internet of Things", Internet of Things Journal, IEEE, 2014, vol. I (2), pp. Il2-12.

[3] Aditya Gaur, Bryan Scotney, et.al, “Smart city architectureand its applications based on IoT”, Procedia Computer Science, Elsevier, 2015, 1089-1094.

[4] W. Juyoung, K .. Byung-In and K. Seongbae, "The rollon-rolloff waste collection vehicle routing problem with time windows", European Journal of Operational Research, Elsevier, 2013, vol. 224 (3), pp. 466-476.

[5] M. Reed, A. Yiannakou and R. Evering, "An ant colony algorithm for the multi-compartment vehicle routing problem", Applied Soft Computing, Elsevier, 2014, vol. 15, pp. 169-176.

[6] K. Buhrkal, A. Larsen and S. Ropke, "The Waste Collection Vehicle Routing Problem with Time Windows in a City Logistics Context", Procedia Social and Behavioral Sciences, Elsevier, 2012, vol. 39, pp. 241- 254.

[7] X. Bing, "Vehicle routing for the eco-efficient collection of household plastic waste", Waste Management, Elsevier, 2014, vol. 34 (4), pp. 719-729.

[8] M. Mes, "Using Simulation to Assess the Opportunities of Dynamic Waste Collection", Use Cases of Discrete Event Simulation, Springer, 2012, pp. 277-307.

[9] V. Hemmelmayr, K. F. Doerner, R. F. Hartl and S. Rath, "A heuristic solution method for node routing based solid waste collection problems", Journal of Heuristics, Springer, 2013, vol. 19 (2), pp. 129-156.

[10] Hui Han, Eva Ponce-Cueto, “Waste collection vehicle routing problem: literature review.”, Promet- traffic and transportation, Vol. 27, 2015, No. 4, 345-358.

[11] Somayeh Fooladi, Hamed Fazlollahtabar et.al, “Waste collection vehicle routing problem considering similarity pattern of trashcan and garbage unloading.” International Journal of Engineering and Management 5, pp.187-198.

[12] Aderemi Oluyinka and olawale Adeleke, “A new model for optimizing waste disposal based on customers time windows and road attributes.” Applied Mathematical Sciences, vol. 10, 2016, no. 42, 2051- 2063.

[13] P. Pratheep, M A Hannan, “Jornal of Applied Sciences Research, 7(7): 1093-1101, 2011.

[14] Arkady Zaslavsky, Alexey Medvedev, “Robust Waste Collection exploiting Cost Efficiency of loT potentiality in Smart Cities", IEEE 2015, International conference on Recent Advances in Internet of Things (RioT).

[15] S.S.Navghane, M.S.Killedar, Dr.V.M.Rohokale, “IoT Based Smart Garbage and Waste Collection Bin”, International Journal of Advanced Research in Electronics and Communication Engineering (IJARECE) Volume 5, Issue 5, May 2016.

[16] Alexey Medvedev, Peter Fedchenkov, et.al, “ Waste management as an IoT- enabled service in smart cities”, 8th International conference on Internet of Things and Smart spaces, ruSMART 2015, At St. Petersburg, Russia, August 2015, DOI: 10.1007/978-3-319-23126-6_10.

[17] Gaurav Kodwani, Mayur Mehta et.al, “ Smart Container- An Automated Alerting System”, International Journal of Computer Applications (0975 – 8887) Volume 155 – No 5, December 2016.

[18] Vikrant Bhor, Pankaj Morajkar et.al, “ Smart Garbage Management System”, International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181 IJERTV4IS031175 www.ijert.org , Vol. 4 Issue 03, March-2015.

[19] Meghana K C, Dr. K. R. Nataraj, “ IoT Based Intelligent Bins For Smart Cities”, International Journal on Recent and Innovation Trends in Computing and Communication (IJRITCC), Volume: 4 Issue: 5, pp. 225-229, May 2016.