Smart Waste Management using Internet-of-Things (IoT)

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***Abstract*—To make the cities greener, safer, and more efficient, Internet of Things (IoT) can play an important role. Improvement in safety and quality of life can be achieved by connecting devices, vehicles and infrastructure all around in a city. Best technological solutions can be achieved in smart cities by making different stakeholders to work together [5][6][7]. System integrators, network operators and technology providers have a role to play in working with governments to enable smart solutions. But, building such solutions on an open, standards-based communications platform that can be continuously used is a challenge.**

We present a waste collection management solution based on providing intelligence to wastebins, using an IoT prototype with sensors. It can read, collect, and transmit huge volume of data over the Internet. Such data, when put into a spatio-temporal context and processed by intelligent and optimized algorithms, can be used to dynamically manage waste collection mechanism. Simulations for several cases are carried out to investigate the benefits of such system over a traditional system. We try to replicate the scenario using Open Data from the city of Pune, India stressing on the opportunities created by this type of initiatives for several parties to innovate and contribute to the development of Smart waste management solutions.

Keywords: Internet-of-Things, smart waste management

I. Introduction

A smart city is nothing but a vision to integrate several information and communication technology (ICT) along with Internet-of-Things (IoT) in a way so as to manage a city's assets [1]. The city's assets include, among others, the local departments, information systems, libraries, schools, hospitals, waste management systems, transportation systems etc. Currently, Indian cities accommodate nearly 31% of current population and contributes to 63% of GDP (Census 2014) [2]. Urban areas are expected to house 40% of India's population and contribute 75% of India's GDP by 2030. This requires comprehensive development of infrastructures pertaining to social, economical, physical, and institutional fields [3]. All are important in improving the quality of life and attracting people and investment. Development of smart cities is a step in that direction.

In this paper, we discuss a smart mechanism for improving the management of wastes in cities. The proposed system is based on the foundation of geographic information systems (GIS), and optimization algorithms. It consists of an IoT based prototype with sensors to measure the waste volume in containers or wastebins, with facility to transmit information over the Internet. The system is simulated in for the city of Pune, using Open Data [3][4]. The simulation covers a period of one month to model wastebin filling and waste collection. The simulations are done for performing an efficiency comparison of different ways for collection of wastes: Traditional method and dynamic on-demand solution, proposed work (intelligent) for several cases. The effect of this work is an combined system model for smart waste collection system. The rest of the paper is organized into the following sections. Proposed work is covered in section 2. Section 3 covers simulation and results of the proposed system. Finally, concluding remarks are given in section 4.

II. Proposed work

We propose a smart waste collection system on the basis of level of wastes present in the wastebins. The data obtained through sensors is transmitted over the Internet to a server for storage and processing mechanisms. It is used for monitoring the daily selection of wastebins, based on which the routes to pick several of the wastebins from different locations are decided. Every day, the workers receive the updated optimized routes in their navigational devices. The significant feature of this system is that it is designed to update from the previous experience and decide not only on the daily waste level status but also the predict future state with respect to factors like traffic congestion in an area where the wastebins are placed, cost-efficiency balance, and other factors that is difficult for humans to observe and analyze. Based on this historical data, the rate at which wastebins gets filled is easily analyzed. As a result, it can be predicted before the overflow of wastes occurs in the wastebins that are placed in a specific location. Depending on economic requirements specified at early stages, the optimized selection of wastebins to be collected is expected

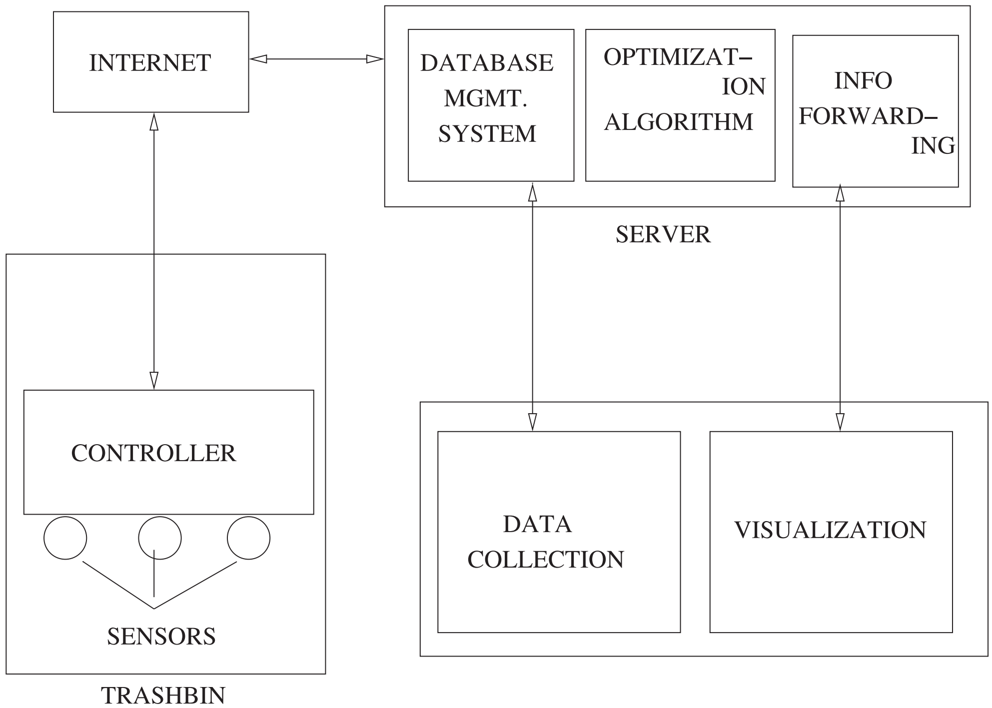

Fig. 1: System Architecture

to improve collection efficiency. Fig. 1 shows the system overview, whose components are briefed as follows.

- Sensors: We can determine the waste level by measuring the distance from the top of the trashbin to the waste by sonar. The sonar that can be used in this prototype should provide measurement from 2cm to 400cm with 3mm accuracy, which is adequate for typical wastebins, e.g., Ultrasonic Ranging Module (HC-SR04). It is essential to optimize the battery usage for achieving bigger lifespan of the devices. Sensing and data forwarding rates, and wireless technology used have a strong influence on energy consumption. Collection and forwarding of data can be done once or twice in a day.
- Access Network Interface: The data collected is sent to a remote server via a wireless link. For our work, WiFi is considered as a network access technology.
- Database: MySql is used for storage of all data collected by the sensors and the trucks.
- Artificial Intelligence (AI): The forecast of waste levels for the future and learning how to select the daily wastebins is based on historical data through artificial intelligence algorithm.
- Optimization algorithms: Once the identification of wastebins have been done, shortest path for collection of same is done. In this work, algorithm 2 is followed for optimization.
- Information adaptation and forwarding: The destination path must be sent to the collectors in understandable format.

Algorithm 1: Smart Waste Management Algorithm

Inputs:
Amount of Wastes generated ;
Number of Wastebins embedded with IoT devices;
Capacity of Wastebins;
Nearest-neighbor shortest path algorithm for finding the optimized routes;
Output: Optimized routes to visit and empty identified Wastebins;
Description:

1: install several wastebins at multiple locations in the city;
2: embed each of wastebins with IoT devices;
3: define threshold value for wastes for each of the wastebins;
4: collect the wastes in the wastebins;
5: send the collected data (using algorithm 3) over the Internet to the servers;
6: store and process the information in the server;
7: calculate and send the optimized routes to send the vehicles for waste collection using algorithm 2;
8: empty the wastes from the identified wastebins;
9: use the collected data for monitoring daily selection of wastebins;
10: predict future traffic in specific location as per algorithm 4;
11: update the optimized routes in navigational devices;

- Visualization for end-user: The path is sent to the end

users via devices such as mobile phones, possibly embedded with cameras. This is to facilitate the driver to easily follow the path.
- Data collection: Data such as GPS locations could help to learn and make better selection of routes.

Cases considered: The cases considered are discussed as follows.

- Case 1: In this case, the servers receive messgage from sensors (embedded within wastebins) from all locations, for waste collection. In this case, vehicle is sent to all the location through the shortest path possible covering all the locations.
- Case 2: In this case, the servers receive messgage from the wastebins, where the wastelevel is more than 70%. In this case, vehicle is sent only to those identified locations from where the messages are received, through the shortest path possible covering all the identified locations.
- Case 3: In this case, the servers receive messgage from the wastebins, where the wastebins are filling at faster rate. In this case, vehicle is sent only to those identified locations from where the messages are received, through the shortest path possible covering all the identified locations.

Algorithm 2: Shortest path spanning tree algorithm (SPST) used by server

Inputs:
Distance from wastebins to worker stations ;
Output: Optimized routes between two points where the wastebin needs to be collected ;
Description:

1: consider street network as a graph;
2: consider street segments as edges and joining points as vertices;
3: calculate an accurate shortest travelling distance between two locations;
4: calculate the distance from one-to-all wastebins to speed up the route optimization process;

III. Simulation and Results

The simulations are carried out using real GIS data of the streets for the city of Pune, India. A total of 5000 wastebins are considered across 10 locations in the city. The rest of the data, and collection strategies required for carrying out the experiments are derived or assumed by the authors (for e.g., we assumed that the wastebins are embedded with IoT devices, and the wastebins are within the driving distance of the workers).

Performance Parameters: Following parameters are assessed.

- Length of the route: It is defined as the driving distance required to collect the selected wastebins for each of the days.

Algorithm 3: algorithm in wastebins sensors

Inputs:
Waste for each day of the week/weekends;
Output: level of wastes in wastebins ;
Description:

1: sense the level of wastes in wastebins every 2 hour during the weekday ;
2: sense the level of wastes in wastebins every 1 hour during the weekend ;
3: compute the rate at which wastebins is getting field ;
4: if the rate is high every 1 or 2 hr, then send message to sever for sending the vehicle for waste collection;
5: if the wastebins level is more than 70% then send the message to the server to send the vehicle for waste collection;
6: if the wastebins level is below 50% then send the message to the server, not to send the vehicle for waste collection;

Algorithm 4: Analysis algorithm used by the servers

Inputs:
Waste level data for each day of the week/weekends;
Output: Predicted waste level data for the coming days ;
Description:

1: get waste level for every day of the week from all wastebins ;
2: observe the changes in the waste levels during the week/weekends;
3: note down the drastic changes during the specific days(s);
4: when wastebins are getting filled faster, send alert to charge/change the batteries (area of research)
5: calculate the distance to wastebins which have significant rise in waste levels;
6: speed up the route optimization process for those days;
7: if the rate fill of wastebins in given area is very high, send alert to municipality to increase vehicles & wastebins;

- Time to cover the route: It is expressed as the time taken to cover the length of the route.
- Cost to collect and dispose off wastes: This is the cost that is associated with garbage cleaning. It is calculated based on daily, weekly, and monthly basis.

Figure 2 shows the results of the simulation of the routes as distances to be covered for collection of wastebins for a total of 5000 wastebins across 10 locations with respect to the three cases considered and compares it with the traditional approach. Compared to the traditional method, where the vehicle is sent to all of the locations irrespective of whether the wastebins are filled or not, the proposed cases performs better. Case 1 adopts shortest path approach to cover all the locations, hence the distance to be covered is optimized. But what if the wastebins

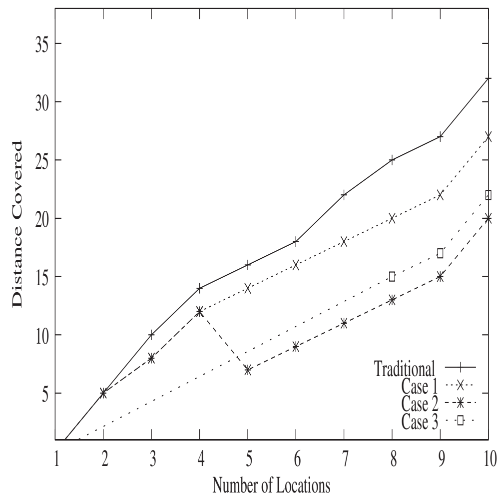

Fig. 2: Distance covered vs number of locations

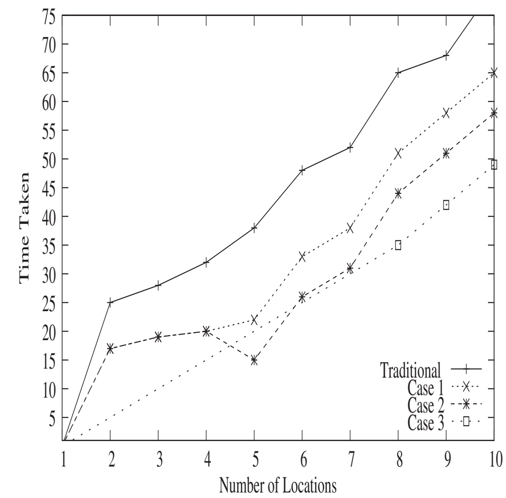

Fig. 3: Time taken vs number of locations

at few locations are not filled at all? Hence, it is wise to visit only those locations, from where the sensors (embedded within the wastebins) send information for waste collection, when 70% of wastebins are filled with wastes. Case 2 gives the optimized distance corresponding to the level of wastes being filled is more than 70%. Case 3 gives the optimized distance corresponding to the rate of wastes fill being more than 10% every 30 minutes.

Figure 3 shows the results of the simulation of the averages of time taken to cover the locations for collection of wastebins for a total of 5000 wastebins across 10 locations with respect to the three cases considered and compares it with the traditional approach. Compared to the traditional method, where the time needs to be spent for covering all the locations irrespective of whether the wastebins are filled or not, the proposed cases performs better. Case 1 adopts shortest path approach to cover all the locations, hence the time is optimized. Case 2 gives the optimized time corresponding to the time spent in visiting locations where the level of wastes filled is more than 70%. Case 3 gives the optimized time corresponding to the rate of wastes fill being more than 10% every 30 minutes.

Figure 4 shows the results of the simulation of the averages of costs spent to cover the locations for collection of wastebins for a total of 5000 wastebins across 10 locations with respect to the three cases considered and compares it with the traditional approach. Compared to the traditional method, where the costs needs to be spent for covering all the locations irrespective of whether the wastebins are filled or not, the proposed cases performs better. Case 1 adopts shortest path approach to cover all the locations, hence the overall cost is optimized. Case 2 gives the optimized cost corresponding to the costs spent in visiting locations where the level of wastes filled is more than 70%. Case 3 gives the optimized cost corresponding to the rate of wastes fill being more than 10% every 30 minutes.

Advantages and the Future Scope: The advantage of this work is its contribution in making a Smart city. Among the many challenges that a city faces, waste management is of utmost importance. This is because, it is directly related to health of people living in the area. We are further extending this work to address problems of seggragating different kind of wastes (e.g., solid, liquid etc.), and identifying different vehicles for collecting it. The optimization algorithms may be devised accordingly depending on the requirements.

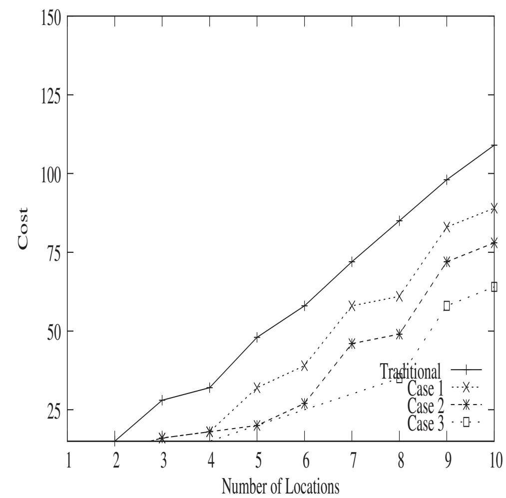

Fig. 4: Cost vs number of locations

IV. Conclusion

We presented an intelligent waste collection system. The system is based on IoT sensing prototype. It is responsible for measuring the waste level in the wastebins and later send this data (through Internet) to a server for storage and processing. This data helps to compute the optimized collection routes for the workers. In future, we would like to enhance the system for different kind of wastes, namely solid and liquid wastes.

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