Chapter 16
A Software-Defined Networking (SDN) Architecture for Smart Trash Can Using IoT

T. Vairam, S. Sarathambekai, and D. Vigneshwaran

16.1 Introduction

Networking as we know it today has been started in the late 1960s and early 1970s. From then, the evolution of network achieved a great height starting from LAN, WAN, cellular network, WLAN to VAN, Adhoc Network, Mobile network, Wireless Sensor Network. There are lot more communication technologies which are added in the queue. Now we are in the era of Internet of Things where any object in the world can act smart according to its purpose on which it has been made and make that object to collect information and transform to the other side of the network through internet. The thought of IoT is simple, the requirement of IoT is not restricted to the frontier and it becomes obligatory in day-to-day living and changes the whole prototype of heritage technology [1]. The object is embedded with the network interface and enables them to communicate with the users. Each object is identified through its unique identification number or IP address. Prior to the IoT era the user can obtain their information only through service provider but now they can obtain the information from any object which is provided with computing and internet facility. The architecture of IoT should be properly designed so that the IoT application will function efficiently. Long-Term Evolution (LTE), ZigBee, Wi-Fi, Z-wave, and Bluetooth are the protocols through which the communication is being accomplished among IoT devices. IoT devices are heterogeneous in nature. Each and every device in an IoT application has their own procedure and rules. The process, services, and hardware everything is predetermined according to its requirement of its respective application. The infrastructure of the IoT environment is fixed in panorama. Further modification of the process or replacement of any

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A. Haldorai et al. (eds.), *EAI International Conference on Big Data Innovation for Sustainable Cognitive Computing*, EAI/Springer Innovations in Communication and Computing, https://doi.org/10.1007/978-3-030-19562-5_16

device's function related to the application will not be performed easily since, this will influence the complete network infrastructure.

It also requires dynamic updation of the network and it has to be done as quick as possible without spending the amount of cost. To conquer this challenge, the design of the programmable network has been initiated which is named as software-defined network (SDN). Software-defined network (SDN) is a next invention of Internet technology which split the functionality of data plane and control plane [2]. The function of control plane is taken away and is placed in a centralized location by means of the server called controller. SDN is a promising technology that meets the demand of IoT as it needs to communicate with different network which is the heterogeneity in nature [3]. SDN also provides central control across the network. As every research stated in their article [3–5], the functionality of the control plane and forwarding plane decoupled in the SDN process. By having central control, SDN helps to automate the network configuration process in an efficient manner. SDN architecture is a layered architecture which includes application layer, control plane layer, and data plane layer. It also includes two interfaces called northbound interface (NI) and southbound interface (SI) through which the layers are communicated. NI is responsible for providing an interaction between application plane and control plane, whereas SI is responsible for providing interaction between the data plane and control plane.

Designing SDN to the IoT applications will be useful thought which make the network configuration process easy. In this paper, we developed the IoT infrastructure for garbage collection and also proposed a SDN architecture for the IoT application which helps to get better performance of data promoting to the processing center in a well-organized manner. In this proposed model, the cloud-based architecture is integrated into the networks along with various software and sensors. The objective of this paper is to propose SDN architecture for smart IoT trash bin to simplify the process of data transferring and to propose a solution for garbage collection system across the city.

The organization of the paper comprises Sect. 16.2 where various related works pertaining to IoT and SDN are discussed. Sections 16.3 and 16.4 have the proposed SDN architecture for smart trash can and proposed IoT-based smart trash can system, respectively. Section 16.5 narrates about the implementation details, and the conclusion is given in Sect. 16.6.

16.2 Related Works

These days, every human activities are knowingly or unknowingly updated in the internet, for example, their account details, travel details, and medicine details. Many applications are built up based on IoT requirement of industry or human which compose an object to labor cleverly by adding the flavor of Internet and computing facilities. Figure 16.1 shows the various fields where the IoT plays a major role and involves everyday individual's living actions that are notified by the IoT devices. Zeinab and Elmustafa presented the diverse IoT applications which

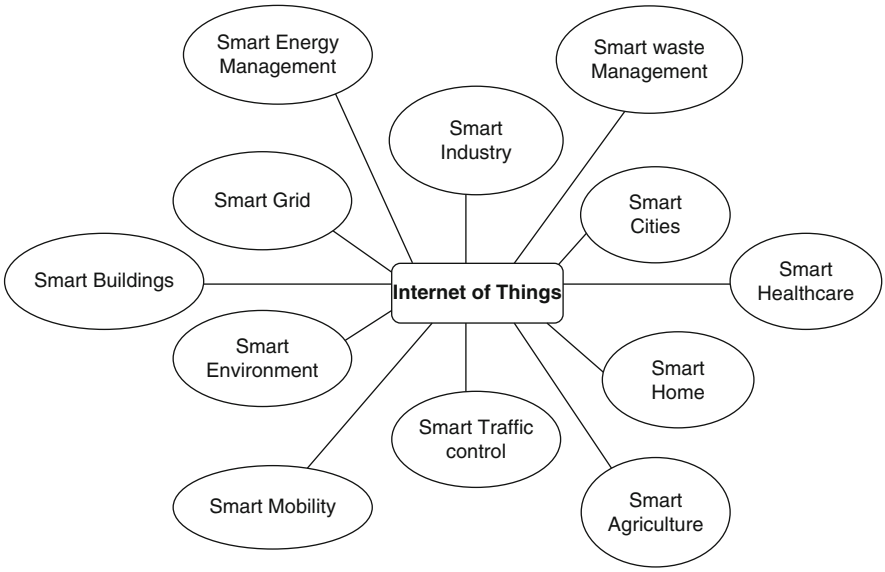

Fig. 16.1 IoT application

eloquent each day of human life will be enhanced and linked with internet through IoT application [6]. Shyam et al. developed the model for waste collection system using IoT infrastructure [7]. In this model the data has been collected and forwarded using internet and also some kind of intelligent algorithms. This model is the dynamic in nature where the collected data are transmitted through internet and using an optimized algorithm the forwarded data are processed.

A novel SDN architecture was introduced which comprises a component named RSU cloud which includes the features of traditional RSU (Road Side Unit), micro scale datacenters, and SDN Controller [4]. Sibylle Schaller and Hood concussed on the SDN architecture, pointed out that the ONF (Open Networking Foundation) architecture working group was the pioneer of the SDN architecture [5]. Samaresh Bera et al. recognized that the conventional networks such as WAN and enterprise network does not have the services which offer support to millions of devices to monitor the surroundings, gather data according to its application, and transmit the collected data to the processing center via internet [8].

Sahoo et al. branded some restrictions in conventional networks as follows: espousing latest protocols in an existing network is very complicated; sustaining hardware from diverse dealer is not feasible due to the closed nature of operating system; and setting up the network infrastructure is costly [2]. SDON (Software-Defined Optical Network) is used for adding optical communication [9]. Sathishkumar et al. developed the IoT-based smart alert system for garbage clearance [10]. The level of garbage bin is monitored based on which the alert signal is given to web server. Then instantaneous cleaning of dustbin will be conceded

out with proper verification. The ultrasonic sensor was used to identify the level of garbage bin. Harika et al. implemented the smart garbage system which is an expensive one as it requires many modules along with the Arduino micro controller like GSM module, GPS module, WIFI module, etc. [11].

16.3 Proposed SDN Architecture

In this section we describe the SDN architecture for smart trash can using IoT. The proposed architecture is given in Fig. 16.2. The main components are SDN Controller, Open Flow, Data line and forward line, Truck and Trash can. The functionality of each component in described in Table 16.1.

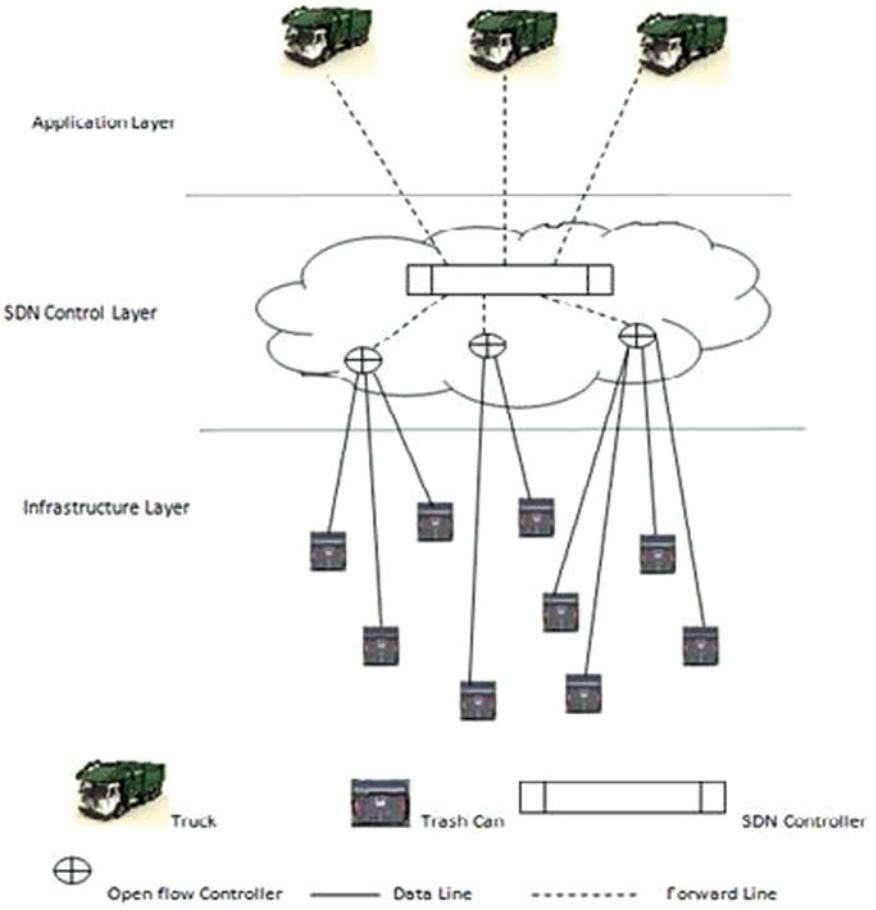

Fig. 16.2 SDN architecture for smart trash can

Table 16.1 SDN architecture components

Component	Description
SDN Controller	SDN controller directly communicates with its network device which has been embedded into trash can through Open flow. SDN controller in turn forwards the data to the application layer. All communication between network device and the application must be done through SDN controller.
Open Flow	It is a protocol which helps SDN controller to separate the control line from the data line. Using Open Flow. SDN obtains information about the path through which the actual data has to be forwarded.
Data line and forward line	It represents the data transfer and control information transfer, respectively.
Truck	It is also considered as one of the component in SDN architecture because the application should be available in the mobile phone of the truck driver.
Trash can	This is provided with raspberry Pi. ultrasonic sensor and wifi module which will perform the tasks of identifying the trash can level and send that information to SDN controller.

The benefits of this approach are: first, centralized management; due to this, the same truck can collect more than one trash can if they are located on the way to another trash can. Hence the time and fuel is reduced. Second, direct programmable capability, for finding shortest path, the algorithm can be changed easily based on its requirements. Third, scope for improvement is always possible without affecting the network infrastructure.

16.4 Proposed Smart Trash Can System

The population of metropolitan city or the urban cities is diversely spread out with some areas highly populated while others have comparatively less population. This makes the process of garbage collection to be a hectic task to the corporation people. Overflowing dustbins causes insanitary circumstance for the people and produces awful aroma around the atmosphere. This will affect the health of the human who live around the place. The current scenario for garbage collection is a very static solution for a very dynamic problem because the amount of trash we produce is not always the same. Hence we have proposed efficient way of collecting garbage's and provide the shortest path to enable the truck driver to reach the location quickly. The workflow of the smart trash can is discussed in this section. HC SR04 ultrasonic sensor and Raspberry Pi are attached to the trash can to measure the trash level. It sends the measured data as a MQTT (Message Queue Telemetry Transport) request through AWS IoT gateway. The Lambda rules are executed and values are updated in DynamoDB table. Then SMS is sent to client application using Amazon Simple Notification Service. The shortest path is calculated and Google map API (Application Programming Interface) shows the shortest path. The various

Table 16.2 Proposed system components and its purpose

Component	Purpose
IoT module	The first step is to measure the amount of trash in the trash can. For this purpose, a Raspberry Pi board is interfaced with ultrasonic sensor (HC-SR04) [12] which is fixed to top of trash can.
AWS IoT	AWS IoT [13] receives the message transmitted by IoT module. It accesses the gateway and reads the incoming messages and forwards it to another end point.
AWS LAMBDA	AWS LAMBDA [14] is a server side event triggered function which will be executed whenever an event occurs.
AWS DynamoDB	It is a unstructured NoSQL database for efficient storage of nonstructured chunks of messages. Amazon Simple Notification Service (SNS) takes care of sending messages.
AWS SNS	Data that is received by Lambda function will be used to send a notification to the AWS SNS topic [15].
Client application	This app is used to monitor the overall status of all trash cans in the city.

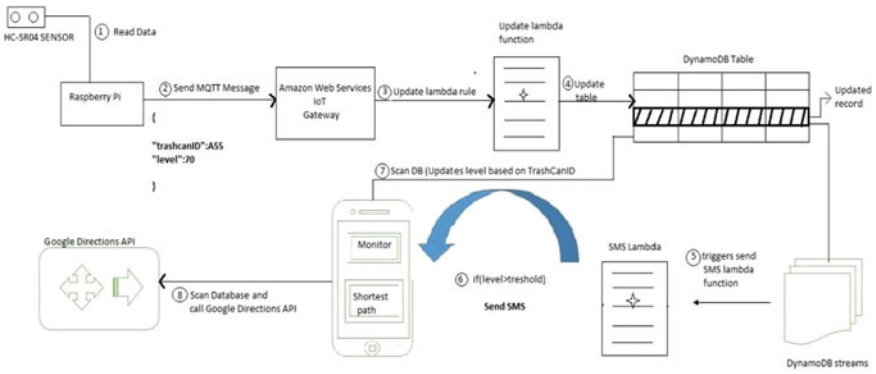

Fig. 16.3 Working process of smart trash can system

components used in the proposed system is given in Table 16.2. Figure 16.3 shows the overall working of Smart Trash Can system.

The advantages of the proposed smart trash can system are the level of the dustbin is updated then and then, the dustbin will be deployed according to the requirement of the people, cost reduction and resource optimization and improves environment quality.

16.5 Implementation and Results

The application is designed for android platforms. The trash level is stored in AWS cloud. The user can monitor the trash level of all trash cans across the city just by using the app and truck driver can find the shortest path using the app. Figure 16.4

Fig. 16.4 User interface

Fig. 16.5 Trash level in all trash cans

shows the user interface in client application. It has two tabs, one to monitor the trash level in different trash can and the figure shows the shortest path to the truck driver so that the filled trash can can be easily emptied.

On clicking the first tab, trash level in different trash cans is shown. With the available details truck driver can also predict when a particular trash can will get filled. The trash can level is shown in Fig. 16.5; the values represent the amount of trash filled in terms of percentage. Figure 16.6 shows the implementation of shortest

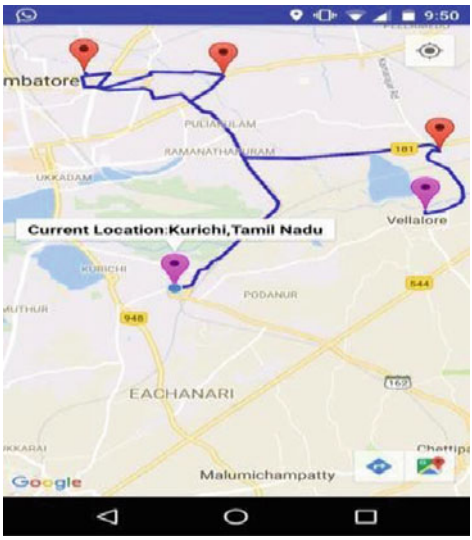

Fig. 16.6 Shortest path to reach the trash can

Fig. 16.7 Database structure

ID	LatLang	Location	Trashlevel
A44	11.020983,76...	Gandhipuram	90
A55	10.9572757,7...	Podanur	2
A33	10.9987351,7...	Singanallur	75
A66	10.9902127,7...	Ukkadam	66
A22	11.0200257,7...	Nava India	85

path algorithm and shows the optimized path to the user. Figure 16.6 shows the optimized path to the truck driver. Shortest path has been calculated using Dynamic Source Routing (DSR) [18]. Here the route is formed on- demand. The current location of the driver and the location of the filled trash can are given as input.

The algorithm finds the shortest path between the truck and filled trash can. The driver can also get to know if there is any other trash can that needs to be collected while reaching the destination. This can be achieved by accessing the client app. The shortest path is displayed with the help of Google app The Google Maps Directions API (2015) [17, 19].

Figure 16.7 shows the organization of database. The trash level changes dynamically in the database. Table 16.3 shows the main salient features of proposed work.

Table 16.3 Salient feature of proposed work

Feature	Description
Cost	Very less hardware is required (Raspberry Pi board and Ultrasonic sensor). Also instead of deploying one board for each trash can, one board is enough for all trash can within a locality. This reduces the cost manifold.
Scalability	Scalability is very high. Since the data is sent to AWS dynamo DB which can be scaled up very easily.
Reliability	The reliability of AWS web services is very high. Over 2000 government web services use AWS including a lot of Defense services [16].

16.6 Conclusion

The novel Software-Defined Networking architecture is proposed for IoT-based smart trash can. A live tracking of trash can is monitored through android app. The app can also be used by the truck driver to identify the trash can and provide the shortest route to reach the trash can as soon as possible. The proposed SDN architecture will help to get better performance of the smart trash can system. IoT-based smart trash can helps the government in solving the critical task of maintaining the health and hygiene of citizens of nation. The proposed solution is cost effective and it is easily deployable and accurate. When deployed in large amounts the garbage collection system can reach higher levels of automation.

References

1. S.K. Lee, M. Bae, H. Kim, Future of IoT networks: survey. Appl. Sci. **7**, 1072 (2017)
2. K.S. Sahoo, S.K. Mishra, S. Sahoo, B. Sahoo, Software defined network: the next generation internet technology. Int. J. Wirel. Microw. Technol. **2**, 13–24 (2017)
3. S.K. Tayyaba et al., Software-Defined Networks (SDNs) and Internet of Things (IoTs): a qualitative prediction for 2020. Int. J. Adv. Comput. Sci. Appl. **7**(11), 385–404 (2016)
4. M.A. Salahuddin, A. Al-Fuqaha, M. Guizani, Software-defined networking for RSU clouds in support of the internet of vehicles. IEEE Internet Things J. **2**(2), 144–197 (2015)
5. Y. Sibylle Schaller, D. Hood, Software defined networking architecture standardization. Comput. Stand. Interfaces **154**, 197–202 (2017)
6. K.A.M. Zeinab, S.A.A. Elmustafa, Internet of things applications, challenges and related future technologies. World Scient. News **67**(2), 126–148 (2017)
7. G.K. Shyam, S.S. Manvi, P. Bharti, Smart waste management using Internet-of-Things (IoT), IEEE Digital Library, in *Proceedings of International Conference on Computing and Communications Technologies (ICCCT)*, 2017
8. Z. Samaresh Bera, S. Misra, A.V. Vasilakos, Software-defined Networking for in ternet of things: a survey. IEEE Internet Things J. **4**(6), 1 (2017)
9. A. Thyagaturu, A. Mercian, M.P. McGarry, M. Reisslein, W. Kellerer, Software Defined Optical Networks (SDONs): a comprehensive survey. IEEE Commun. Surv. Tutorials **18**(4), 2738–2786 (2016)
10. N. Sathishkumar, B. Vuayalakshmi, B. Jenifer Prarthana, A. Sankar, IOT based smart garbage alert system using arduino UNO, in *IEEE Region 10 Conference (TENCON)*, 2016

11. K. Harika, Muneerunnisa, V. Rajasekhar, P. Venkateswara Rao, L.J.N. SreeLakshmi, IoT based smart garbage monitoring and alert system using arduino UNO. Int. J. Innov. Res. Comput. Commun. Eng. **6**(2) (2018)
12. Interfacing HC-SR04, https://electrosome.com/hc-sr04-ultrasonic-sensor-raspberry-pi/, http://www.instructables.com/id/HC-SR04-Ultrasonic-Sensor-With-RaspberryPi-2/
13. AWS IoT, http://docs.aws.amazon.com/IoT/latest/developerguide/IoT-sdk-setup.html
14. AWS LAMBDA, https://aws.amazon.com/documentation/sns/
15. AWS SNS, https://aws.amazon.com/documentation/lambda/
16. AWS, https://aws.amazon.com/government-education/government/
17. Google Developers. Google Maps Directions API Usage Limits, https://developers.google.com/maps/documentation/directions/usage-limits
18. Shortest Path, https://developers.google.com/optimization/routing/tsp#solving-tsps-with-or-tools
19. The Google Maps Directions, https://developers.google.com/maps/documentation/directions/