DOI: 10.15849/IJASCA.221128.08

Int. J. Advance Soft Compu. Appl, Vol. 14, No. 3, November 2022
Print ISSN: 2710-1274, Online ISSN: 2074-8523

LoRa-Based Smart Waste Bins Placement using Clustering Method in Rural Areas of Indonesia

Aa Zezen Zaenal Abidin[1,2], Mohd Fairuz Iskandar Othman[1], Aslinda Hassan[1]
Yuli Murdianingsih[2], Usep Tatang Suryadi[2], Muhammad Faizal[2]

Fakulti Teknologi Maklumat dan Komunikasi (FTMK),
Universiti Teknikal Malaysia Melaka (UTeM)[1]
Melaka, Malaysia
p0131910037@student.utem. edu.my
mohdfairuz@utem.edu.my
aslindahassan@utem.edu.my
Universitas Mandiri[2]
Subang, Indonesia
zezen@universitasmandiri.ac.id
yuli@universitasmandiri.ac.id
usep@universitasmandiri.ac.id
muhammadfaizal@universitasmandiri.ac.id

Abstract

Rural residents have a low level of concern in disposing of waste. This research aimed to obtain an IoT-based method of placing smart waste bins in rural areas. This paper presents a clustering method from the position and distance of each household (LoRa node) to the IoT server point (LoRa gateway) for each available cluster in rural areas. First, determine the number of clusters. Secondly, take the geographic data of each household and measure the household's distance to the IoT server. Thirdly, determine the mean value of the distance of each cluster, and fourthly choosing a household for Smart waste bins placement with how to assess the similarity of the distance of the household's point to the IoT server with the mean value of all the distances in the cluster. The closest similarity is obtained by squaring the value of the result of subtracting the mean by the distance from each household's point to the IoT server, and choosing the smallest value available. To the best of our knowledge, this is the first study that obtained a method to determine the significance of placing smart waste bins based on IoT, especially for rural areas that use the LoRa network. This research has a Good enough cluster after calculating the DBI value. The obtained method has the prospect that can use it to place any object other than the waste bin, where the desired things are at their centroid.

Keywords: *Waste management system, smart waste bins, clustering, LoRa Network, IoT, Rural Area.*

1 Introduction

Rural residents are known from several studies to have low awareness of the surrounding environment, rural residents dump their waste on open dumping sites [1]. Waste disposal facilities in rural areas are still minimal [2], and waste bins such as in rural areas in Indonesia have not been manage and appropriately placed. The placement of waste bins must evoke a sense of belonging, ease access, and fairness of distance for all households.

IoT-based systems are used to help manage waste disposal [3] and to educate resident's rural areas [4], the waste collection by optimizing the shortest path [5], [6], to control waste water treatment [7], [8]. Smart waste bin design and can interact human interaction via remote computer is realized through the mobile terminal[9]. The literature review that has been carried out shows that using IoT, it is possible to track the location of waste containers, monitor the level of landfilled waste, identify locations with the highest demand, suggest the shortest route for optimizing the waste collection, or even interact with residents to encourage disposal at the time of need times when containers bin receive waste, which promotes resident and avoids significant problems due to waste accumulation outside the waste collector [10]. The waste bins are not only used for monitoring but also for clustering their placement as the same a technical characteristics [11].

However, those studies did not explore how to place the waste bins, even though [11] cluster the waste bin, they clustered after they placed, it is only clustering after the waste bins placing. Those studies consider of placing waste bins is only based on optimal routing and operational cost savings.

This study aims to propose a method for placing the IoT-Based of waste bin on the cluster community of the residents in rural areas in Indonesia using LoRa Network. This method was obtained by determining the mean of the distance from every household to the server, and finally, choose the one that similar distance from the household to the server. The main contribution of this paper is to develop a method of placing waste bins in a cluster area using a LoRa network of a group of residents in a rural area based on the position and distance of the nodes to the LoRa gateway. The method in this study can be used to determine anything as an object with it is distance and position.

2 Literature Review

In this section, author should provide the latest related work of the subject matter and critical analyze them. Substantial literatures are expected in this section to ensure the novelty of the proposed work.

A. IoT-Based Waste Bin

They were noticed in the empirical instance of the new waste-dumping system; the IoT waste bin is one aspect of technology, where the information on IoT waste bins can optimize waste collection services [12], [13]. IoT-based Waste bins are defined as waste bins combined with IoT technology used for monitoring or routing collection waste activity [14], [15], [16], [17], [3], waste bins that accept disposal and generate information via IoT infrastructure [10], another name is smart bins [4], [9].

B. LoRa

Communication technologies such as LoRa must integrate various items and provide particular services inside an IoT ecosystem [10], [18]. The LoRa network protocol is suited for low-power IoT applications in real-world urban environments [19], LoRa is a revolutionary Low Power Wide Area Network (LPWAN) technology [20]. Data transfer on the LoRa module shows the benefits of the proposed system, which is achieved using a simple, low-cost, easy-to-use, and replaceable circuit, show the layer of technology as shown in Fig.1 [5]. The LoRa MAC protocol connects the IoT nodes directly to the gateway, which transfers their data; the transmission communication module in an IoT gateway not only sends data to the server via the FireBase API/Host for ESP8266 but also to the user/application within 24 hours, the IoT gateway node must establish contact with all other nodes, the hardware requirements are minimal, as it only needs to host and transfer data for the server, as well as provide a communication interface with nodes [5].

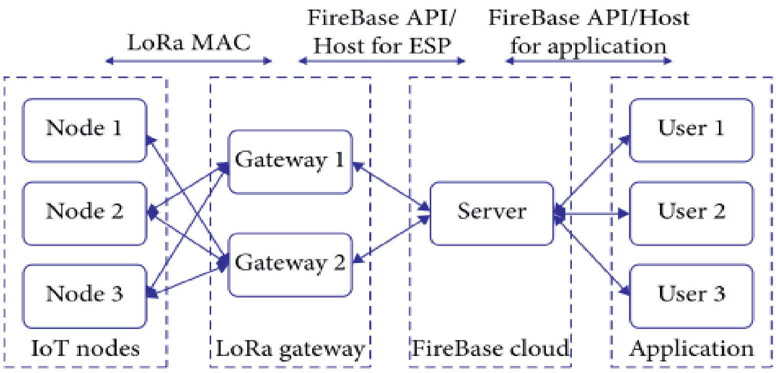

Fig. 1. The implementation of the layer technology in LoRa [5]

C. Waste management in rural area

Waste that is not properly managed in rural areas of developing countries can cause significant environmental contamination [21]. Treatment of categorized rural home garbage is an important part of Indonesia's Rural Revitalization Strategy and addresses people's needs for a better living [22]. Rural areas perform poorly in terms of garbage management. Poor traffic congestion on major highways and landfills necessitates regional government agencies executing extremely broad policies (sanitary inspection, infrastructure development, and community participation), especially in rural areas [1].

D. Davies-Bouldin Index (DBI)

DBI is used to assess the cluster, and the number and proximity of the cluster results data show whether the cluster is excellent or not [23], [24]. Cohesion is a measure of how close the data are to the cluster centers of the clusters that are being followed. DBI is one of the ways used to assess the validity of a cluster in a grouping approach. While the gap is determined by the separation between the cluster's center points. The following are the steps involved in computing the DBI [25], [26], [27]:

1. Sum of Square Within-cluster (SSW).

$$SSW_i = \frac{1}{m_i}\sum_{j=i}^{m_i} d(x_j - c_i) \qquad (1)$$

2. Sum of Square Between-cluster (SSB).

$$SSB_{i,j} = d(c_i, c_j) \qquad (2)$$

3. Ratio calculation (Ratio).

$$R_{i,j} = \frac{SSW_i + SSW_j}{SSB_{i,j}} \qquad (3)$$

4. DBI calculation.

$$DBI = \frac{1}{k}\sum_{i=j}^{k} max_{i \neq k}(R_{i,j}) \qquad (4)$$

3 Methodology

There are five steps for realization methodology in this research. The first is determine the number of the clusters on rural areas. The second is take geographic data of each household and measure the distance of the household to the IoT server. The third is determine the mean value of the distance of each clusters. The fourth is choosing a household for waste bin placement using the fairness distance algorithm. Finally, the fifth is developing smart waste bin for rural areas in Indonesia.

A. Determine the Number of The Clusters

The determination of the number of clusters in this study is by the local government's request. The local government in this study is called dusun. The dusun in this study has two sub-governments called Rukun Warga (RW). The hamlet in this study has two RWs, and each RW has a sub-government under it called the Rukun Tetangga (RT). According to a request from the local government, each RT is divided into two clusters in the placement of waste bins. So that in total, there are 14 clusters in this study, which means there are 14 waste bins. The 14 clusters as shown in Fig. 2.

Fig. 2. The clusters on rural areas

B. Take Geographic Data of Each Household and Measure The Distance of The Household to The IoT Server

Table 1 is a list of residents' houses as members of the 3rd cluster. Each house in the cluster has a geographic address in the form of latitude and longitude, as well as the distance from the resident's home address to the IoT (Distance to the server) server. In row one in Table 1 has a distance of 0.00 m; this shows the house with a distance of 0m to the server is the home address of the resident occupied by the server. The second row of data in Table one has a distance to the server of 43.39 meters. Residential houses with Latitude and Longitude are shown in the second row in Table 1, which are 43.39 m apart are shown in Fig. 3.

Table 1: House hold address at cluster-3

respondents	***Latitude***	***Longitude***	***Distance to The Server***
1	-6547426	107783637	0.00
2	-6547311	107783430	43.39
3	-6547569	107783647	16.04
4	-6547408	107783756	15.30
5	-6547444	107783607	24.13
6	-6547689	107783187	51.70
7	-6546967	107783337	57.82
8	-6547124	107783267	48.87
9	-6547089	107783187	59.42
10	-6547184	107783002	72.43
11	-6547838	107783027	69.44
12	-6547203	107783115	57.78
13	-6547275	107783083	56.45
14	-6547184	107783013	73.29
15	-6547235	107783614	19.12
16	-6547187	107783544	29.15
17	-6547725	107783560	30.82
18	-6547736	107783370	41.09
19	-6547971	107783233	84.86
20	-6547165	107782927	80.66

The yellow line as shown in Fig.3 is distance from household as server IoT to another household with the distance is 43.39 meters.

Fig. 3. Distancae from tehe IoT sercver to the on of households on cluster-3

Table 2 is a collection of data on the home addresses of residents who are in cluster-3. Fig. 4 corresponds to Table 2, which is an example of the distance between residents' houses as far as 243.98 meters, such as the data in the first row in Table 2.

Table 2: House hold address at cluster-1

House holds	***Latitude***	***Longitude***	***Distance to The Server***
1	-6547410	107783765	243.98
2	-6548000	107785886	254.00
3	-6547995	107785968	265.40
4	-6548038	107786384	310.38
5	-6548052	107786468	320.21
6	-6548054	107786572	317.71
7	-6548097	107786564	331.87
8	-6548235	107786479	327.76
9	-6548336	107786544	338.15
10	-6548227	107786619	345.98
11	-6548436	107786712	358.61
12	-6548536	107786779	368,03
13	-6548582	107786842	375.45
14	-6548432	107786803	366.57
15	-6548548	107786786	368.63
16	-6548325	107786150	401.47
17	-6548111	107786766	349.39
18	-6548232	107786031	378.27
19	-6548259	107786861	367.47

Fig. 4. Distancae from the first house hold to server on cluster-1

C. Determine The Mean Value of The Distance of Each Cluster

Table 3 is the result of calculating the average distance from residents' houses to the server from all residents' houses in each cluster. For example, the average distance of residents' houses in cluster 1, where the average distance to the server is 363.3, as assign the value of main score at [28]:

$$Mean\ DS\ Cluster\ 1 = \frac{\sum_{i=1}^{n} Distance\ to\ Server_i}{n} \quad (5)$$

$$Mean\ DS\ Cluster\ 1 = \frac{233.93 + 254.4 + 265.4 + \cdots + 367.47}{19} = 336.28\ meters$$

Table. 3. Mean value for every cluster areas

Clusters	***Mean Values from Distance to The Server***
1	336.28
2	61.33
3	46.58
4	100.56
5	178.73
6	235.92
7	66.25
8	103.85
9	156.07
10	218.24
11	62.50
12	144.11

Clusters	*Mean Values from Distance to The Server*
13	245.62
14	268.91

D. Choosing a Household for Smart Waste Bin Placement

In Fig. 2. The number of clusters is by local government requests. Each cluster has one waste bin that will be shared by all residents in one cluster. To ensure justice for all residents around the cluster, the placement of waste bins must be central. Waste bins are placed on the average distance of all residents' houses in the cluster.

As in table IV, we can imagine there are ten coordinate points. Each coordinate point is mapped in the coordinate diagram in Fig. 5. We can analogize each coordinate point as a resident's house. Table IV can be analogized as ten addresses of house coordinates in one cluster. The coordinate center, which is point 0(0, 0), we make as the point of placement of the IoT server or LoRa gateway. Next, we have to calculate the average value of the distance to the IoT server from all the home addresses in the cluster in Table IV.

The calculation of the distance from point 0(0, 0), the IoT server to other coordinate points in the cluster using the Pythagorean formula as shown in Formula 6. Formula 7 calculates the average distance from all points to the IoT server in one cluster. Formula 8 is used to select the most similar point to the average distance in a cluster, or the point with the shortest distance to the average distance value of the entire cluster. We call the similarity formula from the distance of the existing house to the server with the average distance of all houses to the server, which is in one cluster.

Table. 4. References for decision point for place IoT-base waste bin

point	*x*	*y*	*Distance to The Server*	*Mean of distance on the clusters*	*Similarity(Mean-distance)^2*
1	3	4	5	7.19	4.79
2	4	7	8.06	7.19	0.76
3	5	5	7.07	7.19	0.01
4	6	8	10	7.19	7.89
5	7	4	8.06	7.19	0.76
6	3	2	3.60	7.19	12.84
7	4	5	6.40	7.19	0.61
8	6	3	6.70	7.19	0.23
9	5	6	7.81	7.19	0.38
10	6	7	9.21	7.19	4.11

as same as value of mean opinion score at [28], similarity of the cluster [29]:

$$DS_i = \sqrt{(x_i)^2 + (y_i)^2} \qquad (6)$$

$$Mean\ of\ the\ distance = \sum_{i=1}^{n} \frac{DS_i}{n} \qquad (7)$$

$$Similarity(Mean, DS_i) = Minimum(mean - DS_i)^2 \quad (8)$$

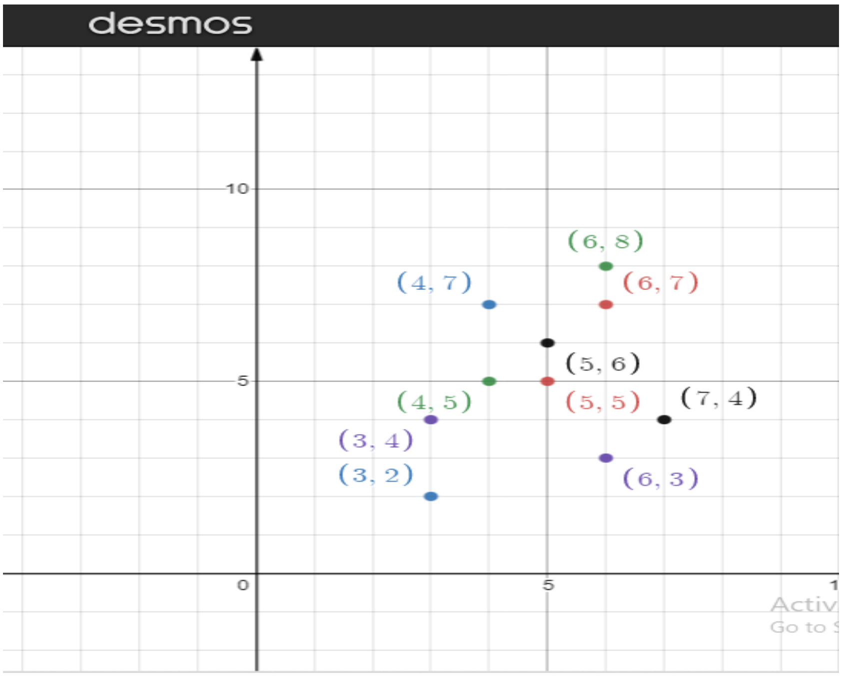

Fig. 5. Desmos coordinat aplications

Fig. 5. using the Desmos application is the realization of the coordinates of Table IV. Each coordinate point in the Desmos application is given a different color. The Desmos application automatically assigns the dots that exist in different colors. Presenting the different colors does not mean anything, only distinguishing the coordinates in the image. The average distance to the server from all points in the cluster is 7.19. The shortest distance from the average length to the server in one cluster as Formula 4 is 0.01, which is the coordinate point on the 3rd row in Table IV, so the chosen point for placing the waste bin in the cluster is the coordinate point (5, 5).

Table V has obtained the geographic points of all houses in cluster 14 in the form of latitude and longitude, obtained using the GPS Coord Camera Application. The distance to the server from each geographical point of the house is obtained by drawing a line from the point of the house to the server point, as shown in Table I. the column value of the average distance in the cluster is calculated using Formula 3. The values in the similarity column are obtained using Formula 4. The closest distance to the average value of the distance to the server in cluster 14 is obtained by residents' houses in row 5; the similarity value of residents' houses for the 5th row is the smallest is 0.82. Residents' houses on line 5, where the latitude value is -6546303, and the longitude value is 107.786859, has a distance of 268 meters from the IoT server and is designated as a place for placement waste bins in cluster 14.

Table. 5. House hold address at cluster-14

respond ents	***Latitude***	***Longitude***	***Distance to The Server***	***Mean***	***Similarity (Mean-distance)²***
1	-6.546575	107.786076	276	268.91	50.26

respondents	*Latitude*	*Longitude*	*Distance to The Server*	*Mean*	*Similarity (Mean-distance)²*
2	-6.546508	107.786107	281	268.91	146.16
3	-6.546484	107.786045	281	268.91	146.16
4	-6.546431	107.786002	275	268.91	37.08
5	-6546303	107.786859	268	268.91	0.82
6	-6.546898	107.785118	257	268.91	141.84
7	-6.546748	107.786002	261	268.91	62.58
8	-6.546575	107.786076	276	268.91	50.26
9	-6.546278	107.785875	268	268.91	0.82
10	-6.546369	107.785849	272	268.91	9.54
11	-6.546191	107.785773	267	268.91	3.64
12	-6.546362	107.78524	245	268.91	571.48

The implementation of choosing the address of a resident's home for the placement of waste bins in the Google Earth application is shown in Fig. 6. The selected point in cluster 14 is drawn a line to the IoT server. Residents' houses on line 5, where the latitude value is -6546303, and the longitude value is 107.786859, has a distance of 268 meters from the IoT server. Latitude value is -6547426, the longitude value is 107783637 for IoT server.

Fig. 6. Implementation for waste bin placement on Google Earth application

Table VI is the result of calculating the similarity value for all clusters. Table VI shows all the closest values for the distance of a resident's house to the IoT server through the smallest similarity value for Cluster 1 (CS-1) to CS-14. So IoT-based waste bins will be placed on all selected home addresses in the cluster as Table VI. Each waste bin becomes a LoRa node that will connect to the server via the LoRa gateway at the server position.

Table. 6. House hold address selected client-server

Clusters	***Latitude***	***Longitude***	***Distance to The Server***	***Mean of The Clusters***	***Similarity (Mean-distance)²***
CS-1	-6548336	107786544	338.15	336.28	0003.49
CS-2	-6547732	107784019	57.03	61.33	0018.49
CS-3	-6547124	107783267	48.87	46.58	0005.24
CS-4	-6547124	107782767	101.27	100.56	0000.50
CS-5	-6548661	107782469	186.78	178.73	0064.80
CS-6	-6548755	-107782219	237.77	235.92	0003.42
CS-7	-6.546604	107.783419	69	66.25	7.56
CS-8	-6.546695	107.784111	100.41	103.85	11.83
CS-9	-6.546737	107.785076	158.35	156.07	5.19
CS-10	-6.546314	107.785335	219.06	218.24	0.67
CS-11	-6546952	107784093	63	62.5	0.25
CS-12	-6546445	107784544	146	144.11	3.57
CS-13	-6.546362	107.78524	245	245.62	0.38
CS-14	-6.546303	107.786859	268	268.91	0.82

E. Developing Smart Waste Bin

Schematically, the IoT system for intelligent waste bins based on the LoRa network consists of waste bins, Master units to sort organic and inorganic waste beside the control LoRa node, Slave units to monitor volume, gas, and weight of waste, LoRa Node on the client side, a LoRa gateway on the server side, Server and internet network, social media in this system using telegram, as shown in Fig.7.

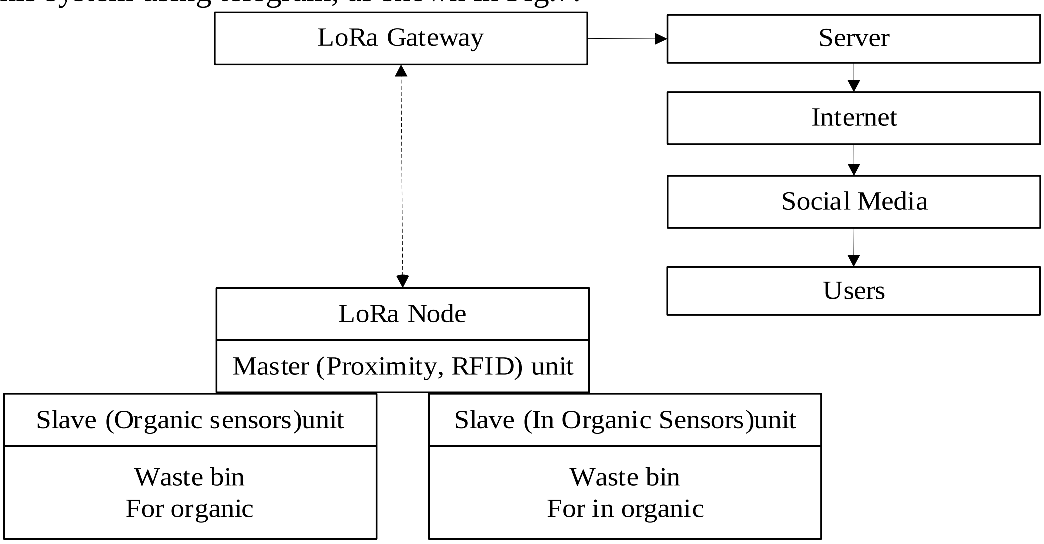

Fig. 7. Diagram schematic system

Monitoring is carried out on the waste's volume, weight and gas content. The volume of waste is obtained from the ultrasonic sensor, the weight of the waste is obtained from the load cell, and the gas content in the waste is obtained from the MQ-4 sensor, as shown in Fig. 8. LoRa gateway on the server side connect to Arduino nano ATmega 328. LoRa Node connect to Arduino Promini. Internet network, or it could be WAN network to facilitate monitoring results information to users.

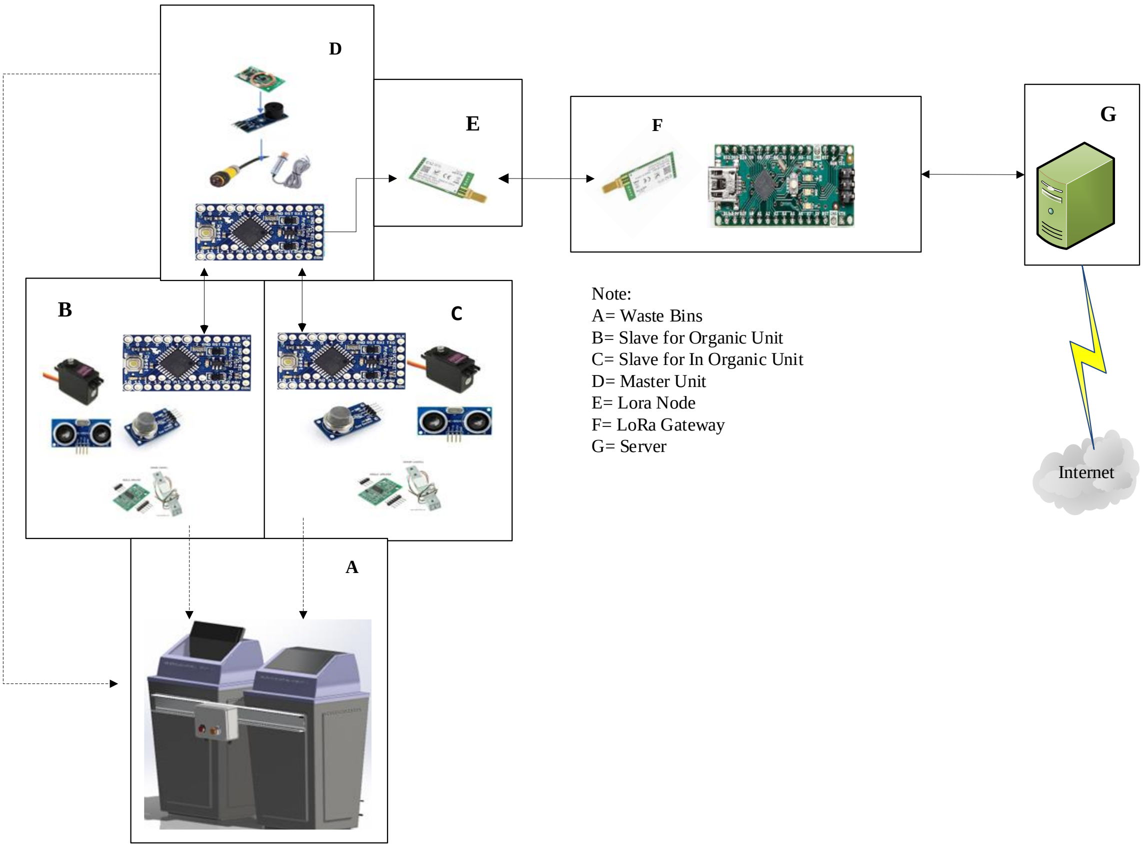

Fig. 8. Electronic components on system

As shown in Fig. 9, LoRa-based smart waste bin. The front view includes an Arduino microcontroller, has been set as master, to act as a LoRa node and an antenna for communication to the LoRa Gateway. The waste bin is equipped with two sensors to carry out the waste sorting process; the first sensor can recognize organic waste, the second sensor can identify inorganic waste. A more detailed explanation will be discussed in a separate session.

Fig. 9. The front side of the smart waste bin

Fig. 10 is a back view of a LoRa-based waste bin. Two Arduinos have been set as slaves. The main function of the Arduino microcontroller is to process the action of opening and closing the waste bin and monitoring the garbage in the waste bin by using related sensors. More detailed explanation will be given in another session.

Fig. 10. The Back side of the smart waste bin

Fig. 11 is the LoRa Gateway and the antenna connecting all the LoRa nodes of the 14 existing clusters. LoRa gateway can be connected to a web server using a USB connector. Next, the system can be connected to the IoT platform, a cloud application via the internet.

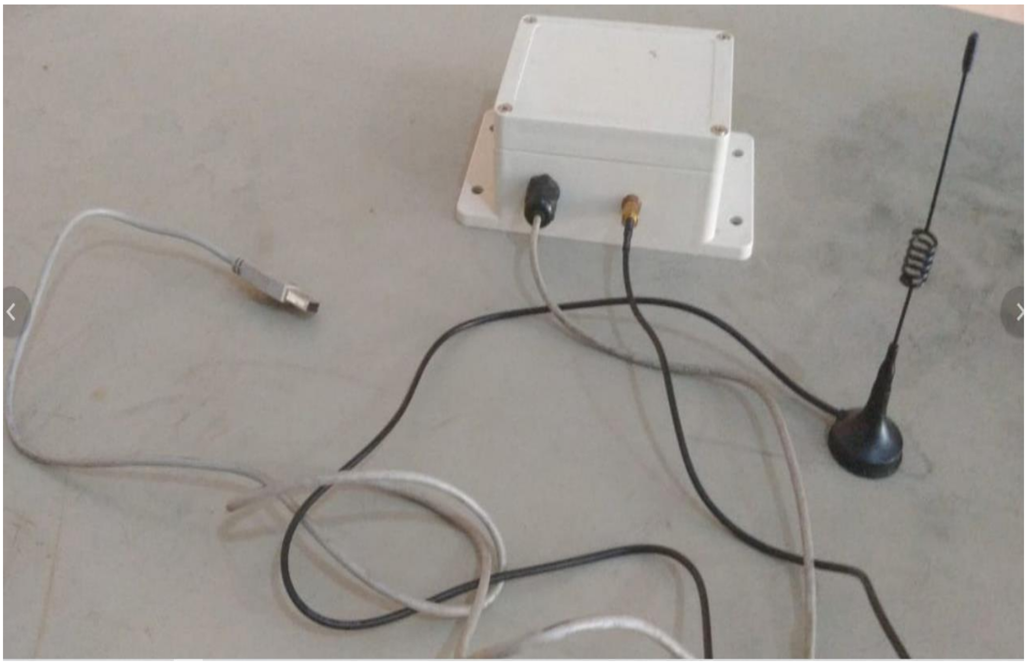

Fig. 11. The gateway of the LoRa

An analogy to prove the placement of waste bins in one cluster is shown in Fig. 5. The selection of the point of placing the waste bins at the coordinate point obtained satisfactory results. The waste bins has been placed in the point (5, 5). The point is visually proportional in the middle of all the existing coordinate points. Determination of clusters, determining the coordinates of Residents' houses, calculating the average distance of Residents' homes to the IoT server (LoRa gateway), choosing waste bins based on the similarity of the distance between residents' houses and the average value in one cluster as shown in the case in cluster 14, which is shown in Fig. 6, by caste the eye also occupies a proportionately central to the houses of other residents.

In this study, we considered the suitability of the number of members in the cluster with the capacity of the waste bins. The waste bins in this study have a capacity of 120 kg; there are two waste bins with 60 kg each for organic and inorganic waste, with an estimated 5 kg of waste per household.

In this study, LoRa network communication media is used. With LoRa guarantees the use of energy-efficient power sources, can use batteries for up to 10 years. The range of the LoRa type E32 used in this study ensures a range of 8 km. The author ensures that all waste bins reach the communication network to the IoT Server. The focus of placing waste bins is only on affordability fairly, using the average distance of each house to the IoT server.

In contrast to [3], [4], [6], [9], [11] not yet using LoRa, still using wifi, only [5] already using LoRa, without any waste sorting device, not discussing the placement of the waste bin. In fact, with the various parameters required, it is very important to consider the placement of waste to optimize collecting and disposing of waste. In this study using Lora, there is a waste sorting facility. There is an facility to identify each resident in the cluster, perform cluster formation according to user needs, and use the method of placing waste bins.

The method of placing waste bin based on clusters requested by the local government, placement of waste bins based on the calculation of the similarity of places with the average distance of all residents' houses in the cluster (shortest distance), especially in rural areas, allows improving the quality of better waste disposal practices. The selection of a place that has similarities to the average distance of all cluster members in a cluster can be applied in the placement of various objects that need to be central to all other cluster members. These objects include speakers, wifi for internet access, cameras that reach 360 degrees, and others.

Table 7. is the result of calculating the SSW value from the 14 existing clusters. The SSW value becomes a reference in determining the SSB value, ratio value, and DBI value. The SSB value is 9665.776, the ratio value is 0.033652, the DBI value is 0.033653. The DBI value obtained is minimal. This shows the excellent quality of the existing clusters.

Table. 7. SSW values of the clusters

Clusters	***SSW***
CS-1	33.572
CS-2	19.112
CS-3	20.025
CS-4	18.572
CS-5	48.772
CS-6	15.101
CS-7	20.458
CS-8	28.892
CS-9	27.277
CS-10	13.553
CS-11	23.833
CS-12	23.456
CS-13	24.739
CS-14	7.917

4 Conclusion and Future Work

This study aimed to propose a method for placing the IoT-Based of waste bin on the cluster of the residents in rural areas in Indonesia using LoRa Network. In this study, we have discussed and proved the method of placing waste bins that uses LoRa network media in rural areas. The method has five steps. The first is determine the number of the clusters on rural areas. The second is take geographic data of each resident’s house and measure the distance of the household to the IoT server. The third is determine the mean value of the distance of each clusters. Fourth, choosing the point for placing the waste bin by selecting a resident's house with the same distance as the mean of all residents' houses to the IoT server in the cluster. We have good enough cluster after calculated DBI value for evaluation clusters. All electronic devices are low-power, requiring voltage support starting from 5 volts DC. Especially the use of LoRa network technology was chosen as the latest technology that can last decades from a low-power battery. In this study, IoT-based smart waste bins using LoRa Network technology have been able to sort organic and inorganic waste and monitor the volume, gas content, and weight of waste in waste bins. The following work in the placement of waste bins is an algorithm for placing waste bins adaptively to various parameters in the location and related to waste disposal practices in rural areas.

References

[1] S. Boateng, P. Amoako, D. O. Appiah, A. A. Poku, and E. K. Garsonu, "Comparative Analysis of Households Solid Waste Management in Rural and Urban Ghana," *J. Environ. Public Health*, vol. 2016, pp. 7–10, 2016, doi: 10.1155/2016/5780258.

[2] A. Wang, L. Zhang, Y. Shi, S. Rozelle, A. Osborn, and M. Yang, "Rural solid waste management in China: Status, problems and challenges," *Sustain.*, vol. 9, no. 4, pp. 1–18, 2017, doi: 10.3390/su9040506.

[3] R. Karthikeyan, R. Kumar, P. G. Bhat, M. P. Kumar, and R. M. Priya, "Garbage bin monitoring system using IOT," *AIP Conf. Proc.*, vol. 2271, no. September, 2020, doi: 10.1063/5.0024753.

[4] S. M. Ahmed, T. S. Chandu, G. Rohith, G. Naveen, and S. Naveen, *IoT Based Garbage Disposer for Educating Rural India*, vol. 601. 2020. doi: 10.1007/978-981-15-1420-3_101.

[5] T. A. Khoa *et al.*, "Waste Management System Using IoT-Based Machine Learning in University," *Wirel. Commun. Mob. Comput.*, vol. 2020, Arti, p. 13, 2020.

[6] T. M. N. Vamsi, G. Kalyan Chakravarthi, P. Lanka, and B. Divakar, "An IoT Based Smart Garbage Monitoring and Disposal Support System," *Proc. - 5th Int. Conf. Comput. Methodol. Commun. ICCMC 2021*, no. Iccmc, pp. 438–442, 2021, doi: 10.1109/ICCMC51019.2021.9418289.

[7] P. C. P. De Silva and P. C. A. De Silva, "Ipanera: An Industry 4.0 based architecture for distributed soil-less food production systems BT - 2016 Manufacturing and Industrial Engineering Symposium, MIES 2016, October 22, 2016," *1st Manuf. Ind. Eng. Symp.*, no. October, 2016.

[8] H. P. Hanifah and S. H. Supangkat, "IoT-based River Water Quality Monitoring Design for Smart Environments in Cimahi City," *Proc. Int. Conf. Electr. Eng. Informatics*, vol. 2019-July, no. July, pp. 496–499, 2019, doi: 10.1109/ICEEI47359.2019.8988883.

[9] A. Zhang, P. Zhuang, Y. Shi, and D. Zhao, *Design of Intelligent Classification Waste Bin with Detection Technology in Fog and Haze Weather*, vol. III. 2018.

[10] K. Pardini, J. J. P. C. Rodrigues, S. A. Kozlov, N. Kumar, and V. Furtado, "IoT-based solid waste management solutions: A survey," *J. Sens. Actuator Networks*, vol. 8, no. 1, 2019, doi: 10.3390/jsan8010005.

[11] Z. Oralhan, B. Oralhan, and Y. Yiğit, "Smart city application: Internet of Things (IoT) technologies based smart waste collection using data mining approach and ant colony optimization," *Int. Arab J. Inf. Technol.*, vol. 14, no. 4, pp. 423–427, 2017.

[12] P. Jiang, Y. Van Fan, J. Zhou, M. Zheng, X. Liu, and J. J. Klemeš, "Data-driven analytical framework for waste-dumping behaviour analysis to facilitate policy

regulations," *Waste Manag.*, vol. 103, pp. 285–295, 2020, doi: 10.1016/j.wasman.2019.12.041.

[13] T. Bányai, P. Tamás, B. Illés, Ž. Stankevičiūtė, and Á. Bányai, "Optimization of municipal waste collection routing: Impact of industry 4.0 technologies on environmental awareness and sustainability," *Int. J. Environ. Res. Public Health*, vol. 16, no. 4, 2019, doi: 10.3390/ijerph16040634.

[14] T. Anagnostopoulos and and S. H. Zaslavsky, Arkady Zaslavsky, Kostas Kolomvatsos, Alexey Medvedev, Pouria Amirian, Jeremy Morley, "Challenges and Opportunities of Waste Management in IoT-Enabled Smart Cities : A Survey," vol. 2, no. 3, pp. 275–289, 2017.

[15] F. Zhang, C. Cao, C. Li, Y. Liu, and D. Huisingh, "A systematic review of recent developments in disaster waste management," *J. Clean. Prod.*, vol. 235, pp. 822–840, 2019, doi: 10.1016/j.jclepro.2019.06.229.

[16] P. Argulwar, S. Borse, and K. N. Argulwar, "IoT-Based Smart Garbage Management System," pp. 237–245, 2018, doi: 10.1007/978-981-10-5520-1.

[17] B. Prasad, S. Dalmia, S. Dasari, and N. Arya, "An Intelligent Bin Management System Design for Smart City using GSM Technology," *2018 7th Int. Conf. Reliab. Infocom Technol. Optim. Trends Futur. Dir. ICRITO 2018*, pp. 557–563, 2018, doi: 10.1109/ICRITO.2018.8748636.

[18] abhay shankar Bharadwaj, R. Rego, and A. Chowdhury, "IoT Based Solid Waste Management System," 2016.

[19] M. J. Beliatis, H. Mansour, S. Nagy, A. Aagaard, and M. Presser, "Digital waste management using LoRa network a business case from lab to fab," *2018 Glob. Internet Things Summit, GIoTS 2018*, pp. 1–6, 2018, doi: 10.1109/GIOTS.2018.8534562.

[20] M. Saravanan, A. Das, and V. Iyer, "Smart water grid management using LPWAN IoT technology," *GIoTS 2017 - Glob. Internet Things Summit, Proc.*, 2017, doi: 10.1109/GIOTS.2017.8016224.

[21] Z. Han *et al.*, "Characteristics and management modes of domestic waste in rural areas of developing countries: a case study of China," *Environ. Sci. Pollut. Res.*, vol. 26, no. 9, pp. 8485–8501, 2019, doi: 10.1007/s11356-019-04289-w.

[22] Z. Fan and J. Wang, "Model and Suggestions on Classified Treatment of Rural Domestic Waste," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 781, no. 3, 2021, doi: 10.1088/1755-1315/781/3/032023.

[23] Y. A. Wijaya, D. A. Kurniady, E. Setyanto, W. S. Tarihoran, D. Rusmana, and R. Rahim, "Davies Bouldin Index Algorithm for Optimizing Clustering Case Studies Mapping School Facilities," *TEM J.*, vol. 10, no. 3, pp. 1099–1103, 2021, doi: 10.18421/TEM103-13.

[24] G. Du, X. Li, L. Zhang, L. Liu, and C. Zhao, "Novel Automated K-means++ Algorithm for Financial Data Sets," *Math. Probl. Eng.*, vol. 2021, 2021, doi: 10.1155/2021/5521119.

[25] M. Gao *et al.*, "Identification Method of Electrical Load for Electrical Appliances

Based on K-Means ++ and GCN," *IEEE Access*, vol. 9, pp. 27026–27037, 2021, doi: 10.1109/ACCESS.2021.3057722.

[26] A. Ilham, R. S. Wahono, C. Supriyanto, and A. Wijaya, "U-control chart based differential evolution clustering for determining the number of cluster in k -means," *Int. J. Intell. Eng. Syst.*, vol. 12, no. 4, pp. 306–316, 2019, doi: 10.22266/ijies2019.0831.28.

[27] B. Jumadi, "Tesis:peningkatan hasil evaluasi clustering davies bouldin dengan penentuan titik pusat cluster awal K means," 2018, [Online]. Available: https://repositori.usu.ac.id/bitstream/handle/123456789/3827/157038047.pdf?sequence=1&isAllowed=y

[28] F. A. R. Mu'Amar Wildan, E. A. Z. Hamidi, and T. Juhana, "The design of application for smart home base on LoRa," *Proc. - 2020 6th Int. Conf. Wirel. Telemat. ICWT 2020*, 2020, doi: 10.1109/ICWT50448.2020.9243648.

[29] K. Parthiban and S. Sujatha, "Similarity-based clustering and security assurance model for big data processing in cloud environment," *Econ. Comput. Econ. Cybern. Stud. Res.*, vol. 52, no. 2, pp. 175–200, 2018, doi: 10.24818/18423264/52.2.18.11.

Notes on contributors

Aa Zezen Zaenal Abidin is Ph.D candidate from UTeM, Melaka, Malaysia. Senior lecturer at the Department of Informatics, Universitas Mandiri, Subang, West Java, Indonesia. His main teaching and research interests include IoT, Data Science, Database, Web Programming, Object Oriented Analysis and Design.

Mohd Fairuz Iskandar Othman (Member, IEEE) received the Ph.D. degree in information technology from the Queensland University of Technology and the master's degree in internetworking from the University of Technology, Sydney. He is currently a Senior Lecturer with the Department of Computer Systems and Communication, Faculty of Information and Communication Technology, FTMK (UTeM). His research interests include human behavioral issues in Information Security, IT governance and management, and other related topics in computer networks and computer security.

Aslinda Hassan earned her B.Sc. in Business Administration majoring in Management Information System (MIS) from University of Pittsburgh, USA; and M.Sc. in Computer Science from University of Technology, Malaysia in year 1998 and 2001 respectively. She obtained her Ph.D. degree in Electrical Engineering in 2014 from Memorial University of Newfoundland, Canada. She was a lecturer at University of Technology, Malaysia (UTM) in 2003 and and currently a senior lecturer in Universiti

Teknikal Malaysia Melaka (UTeM) since 2004. She is also the head of Information Security Forensics and Computer Networking (INFORSNET) research cluster. Her research interests include network performance modelling and analysis; network protocols in wireless ad hoc network and vehicular ad hoc networks; and network programming interfaces.

Yuli Murdianingsih is Senior Lecturer at the Department of informatics, Universitas Mandiri, Subang, West java, Indonesia..Her main teaching and research interests include Data Science, Artifiacial Intelligence.

Usep Tatang SUruyadi is Senior lecturer at the Department of Informatics, Universitas Mandiri, Subang, West Java, Indonesia .His main teaching and research interests include Data Science, Discrete Mathematics, Numerical Methods, Object Oriented Analisys and Design.

Muhammad Faizal. is Senior lecturer at the Department of Mathematics Education, Universitas Mandiri, Subang, West Java, Indonesia. His main teaching and research interests include Discrete mathematics, Computer Programming, Computer Organization and Architecture.