Trust aware crowd associated network-based approach for optimal waste management in smart cities

Trust Aware Crowd Associated Network-based Approach for Optimal Waste Management in Smart Cities

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Abstract

Waste management has been a serious issue in urban areas due to the population growth. An appropriate solid waste management system is needed to improve the cleanliness of the environment. On the other hand, the rapid growth of the wide adoption of the Internet of Things (IoT) within the context of smart cities has motivated numerous number of studies investigating new solutions that could be helpful in mitigating and solving the waste management issue. Despite the existence of such methods have been introduced and used in managing waste's location, volume and the optimal path for collection, yet these IoT based technologies are vulnerable to misinformation kinds of cyber attack. Consequently these types of attacks will yield crucial impact on the decided collection path and the frequency of garbage trucks visiting the fake reported waste points, which obviously costs money and time. Hence, this chapter proposes a trusted crowd associated network architecture that uses a group of components to monitor waste and provide optimum collection route for the garbage truck. Netlogo a multi-agent platform has been used to simulate a real time monitoring on waste management as a proof of concept. Our proposed approach measures the waste level data then updates and records them continuously. An optimal route will then be provided to the garbage truck for the optimal waste's collection once a certain number of bins have reached a predefined threshold (combination of weight and height values). Three simulation scenarios are defined, implemented, and their results have been validated. The performance measure shows that our proposed solution could provide an aid waste management companies in reducing cost and time in the waste collection process, which supports the integration plans of IoT technology within smart cities.

Keywords: Waste Collection; Simulation; Net logo; Route Optimisation; Crowd Associated

1. Introduction

The Internet of Things (IoT) is a recent communication paradigm that envisions a near future, in which things are commonly used in a daily life. These things are representing sensors that are integrated with microcontrollers, transceivers for digital communication, and protocol stack that helps the objects/things to have the ability to communicate with one another as well as with the users, becoming an integral part of the Internet (Zanella, Bui, Castellani, Vangelista, & Zorzi, 2012). In short, any thing that can be connected to the Internet and controlled from devices that lying behind an Internet Protocol (IP) address would be part of the wide-network named IoT.

Nowadays, waste management has been an issue for many years especially in cities where they are densely populated. Inefficient waste management will cause overflowing garbage bin, which will cause harm to the environment leading to human health deteriorate. An example of inefficient waste management is the current system where garbage collector follows a fixed route to collect garbage from streets and houses on a fixed time and day based on a predefined schedule. This is not efficient due to the fact that the garbage bin will be eventually left unattended for an amount of time until the garbage collector comes for the collection in the next pointed date and time. During the time, there will be a possibility where more and more garbage accumulated, which will cause overflowing the dustbin. Moreover, the conventional collection system is inefficient, since there will be scenarios where some of the garbage bins will not reach a proper collection level, but the garbage collector still collects the, as it is part of their routine. This will cause waste of fuel and time need to be covered by the waste management authorities. This could be avoided when garbage collector obtains a verified genuine notification from the smart garbage bin only when it gets a proper amount of waste, additionally will be provided with the shortest path to the garbage bin as an application of smart-city-based-IoT technology.

2. Related Work and Problem Definitions

Many researchers have proposed several solutions to manage the problems associated with garbage management. For instance, the authors in (Mamun, Hannan, Hussain, & Basri, 2015) have designed an intelligent solid waste bin that collects data in real time. The intelligent solid waste bin was integrated with various sensors to obtain the actual fill level of the smart bin. The authors have also used decision algorithm for their monitoring application to sense solid waste data. However, the authors' proposed work only focus on the design of the bin without including discussion on optimizing the cost of garbage collection.

On the other hand, the authors in (Catania, Ventura, & Daniela, 2014) proposed a system where the Smart Waste M3 platform is adopted for Smart Waste Management. The Smart M3 platform is an open source project that allows different entities to share information and also cooperate in a transparent way to the heterogeneities of different sensory data (Catania, Ventura, & Daniela, 2014). By doing so the proposed platform could interconnect heterogeneous devices and sharing data with a large number of people. The authors also integrated two sensors, which is the proximity sensor and the weight sensor attached to the garbage bin for real-time monitoring. The author shows several simulations with a map full and half-full garbage bin, besides the garbage collectors were sent to collect the assigned waste bins within a specified region. Though, the system lacks of scheduling and routing facilities that should be available for the garbage collector, which supports the advancement of smart cities.

As another attempt by (Sanjeevi & Shahabudeen, 2016) an objective was stated to minimize the total collection's accumulated distance. In the beginning, the author addressed the issues of solid waste transportation issue in Chennai city at India. Thus, the authors have suggested using the Geographic Information System (GIS) application and Dijkstra algorithm to identify the optimal routes for 13 selected garbage bins out of total 200 garbage bins. By doing so, the proposed solution was able to reduce waste collection distance, thus reducing the time and cost. However, their proposed method did not consider the possibility of fake-shared information that could lead for overwhelming the entire system.

In contrast, another related system has been proposed by (Hannan, Arebay, Begum, & Basri, 2011) where the Radio-frequency identification (RFID) and other communication technologies such as Global Positioning System (GPS), GIS and GSM/GRPS digital cellular are integrated into the garbage bin as well as the truck for real-time tracking and waste monitoring. The RFID tag is attached to the garbage bin while the RFID reader is attached to the Garbage Collector truck. The reading process converts radio waves emitted by the waste bin into digital information. The garbage bin is also equipped with a camera to detect the level of the garbage bin. The system would capture an image of the garbage when the garbage collector is within the vicinity of the garbage bin. Nevertheless, the proposed system does not obtain in real-time the bin's status data, thus it solely depends on the historical data to estimate the actual content of the garbage bin. The authors also did not discuss the scheduling and routing for the garbage collection's process.

While the authors in (Faccio, Persona, & Zanin, 2011) have proposed quite similar system as the one in (Hannan, Arebay, Begum, & Basri, 2011), they integrated RFID, GPS, and GRPS into the garbage bin and truck. The difference is that the garbage bin is equipped with different sensors and the weighing sensor has been equipped on the vehicle to detect the loaded waste so that they could detect the available capacity of the vehicle instantly. The author introduced a new heuristic routing model, which consists of Saving methods, Sweep algorithm, Nearest neighbor and tabu search.

The other way around, in (Mamun M. A., Hannan, Hussain, & Basri, 2013) authors proposed a solution that developed a wireless sensor network, which consists of three-tier architectures. The garbage bin in this system is integrated with several sensors such as temperature, weight and humidity sensors. The data collected by the sensors would be delivered to the servers by using GSM/GRPS. The control station will continuously analyse the received data and update the garbage bin's information. A web-based program is run on the server to manage the data and also monitor the status of the garbage bin, the program allows users to monitor the bin status. The authors considered the minimum energy consumption and less operation cost by avoiding GRPS in every bin. Yet, the authors did not consider any third-party involvement, which could help in reporting or passbying information of waste's location and quantity from areas where network coverage not exist within a smart city.

In order to address the aforementioned challenge of the availability of network infrastructure, authors in (Azad, Rahman, Asyhari, & Pathan, 2017) proposed an efficient infrastructure-less network called crowd-associated network that uses a set of crowds to fill in communication gaps among the components. They have called their crowd volunteer agent while relay data from a component to others component until it reaches its destination. The author focuses on reducing the cost of deployment and maintenance cost of the infrastructure. The genetic algorithm was applied in this article to find a feasible trade-off between distance and cost. However, the authors did not consider the authenticity of the data sent by the suggested volunteer agent. Since the data is not verified, malicious volunteer agent may send fake data into the network, which may cause garbage collectors to go a further distance to collect fake reported garbage bins. Table 1 shows a list of related work along with their main features.

Table 1. Related Works with their Features

Related Article	Technique used for Garbage Measurement	Garbage Level Measurement	Weight of the Garbage Measurement	Scheduling and Routing Consideration	Method for Routing Solution	Third Party Involvement
(Mamun, Hannan, Hussain, & Basri, 2015)	Ultrasonic sensor	Yes	Yes	No	-	None
(Catania, Ventura, & Daniela, 2014)	Proximity Sensor	Yes	Yes	No	-	Human
(Hannan, Arebay, Begum, & Basri, 2011)	Image Processing	Yes	No	No	-	None
(Faccio, Persona, & Zanin, 2011)	Ultrasonic	Yes	No	Yes	A heuristic routing model consist of (Saving methods, Sweep algorithm, Nearest neighbour and tabu	Human
(Sanjeevi & Shahabudeen, 2016)	-	-	-	Yes	Dijkstra Algorithm	None
(Mamun M. A., Hannan, Hussain, & Basri, 2013)	Sensors	Yes	Yes	No	-	None
(Azad, Rahman, Asyhari, & Pathan, 2017)	Sensors	Yes	-	No	-	Volunteer Agents
My Project	Ultrasonic	Yes	Yes	Yes	Dijkstra Algorithm	Volunteer Agents

From the given discussion on the related work within this section, the main objective of our study is to propose a trust-aware crowd associated network-based approach that computes an optimum path for the garbage collector when the garbage bin is filled. In the following section, we will explain the key concept of crowd-associated network to provide the readers with a brief background on its functionality.

2.1 Crowd Associated Network

A set of crowds that plays a significant role in filling the communication gaps with others associate and becomes an inseparable part in the network is called Crowd Associated Network (CrAN). In CrAN, there are two kinds of components; a dedicated agent and a non-dedicated agent. The dedicated agent is where components are installed in the network to perform a specific task. These types of agents are fixed in a place and would exchange information with the non-dedicated agent to achieve its goal. Whereas, for the crowd that is a non-dedicated agent, where agents act as an intermediate relay within proposed network architecture. The non-dedicated agents would retrieve data from the dedicated agents and delivers the data to the other dedicated agents. The non-dedicated agents may also exchange information within themselves to increase the chances of the data reaching the dedicated agents and increase its performance. A side note is that anyone can be part of the crowd if they comply with the network requirement. Those that are interested to be part of the crowd would be given a network component to be installed in their vehicles. We will refer in this chapter to the crowd as volunteer agent (VA) as the crowd is volunteering themselves to be part of the network. In the Crowd Associated Network, there will be five main components: smart garbage bin, volunteer agents, Access Point (AP), control centre and garbage collector. The joint effort of these components will allow necessary data to be delivered and also compute an optimum path.

3 Proposed Method

In this section the overview of our proposed method will be demonstrated in additional to the network architecture, data transmission method, the waste collection route optimization algorithm, simulation setup and evaluation method.

3.1 Overview

This project requires a smart waste garbage bin (SGB) to be implemented in smart cities to monitor the level of rubbish of the garbage bin. The SGB will be embedded with multiple sensors to measure the weight and level of the garbage bin. In the SGB, there will be an IoT device that has the ability to acquire the information of the SGB and transmit the information to nearby associates, which is mainly VA. Once the level and weight of the garbage bin reach a certain threshold, the SGB would generate Data packets that contain information of the garbage bin and start sending them to VAs that are within the range. VA that receives the data packets will then relay the data to other associates until it reaches its destination, which is the AP. After that, the recipient AP would forward the data packets to the Control Centre (CC) for further processing. Once the CC receives that data, it will process the data packets and stores them accordingly. When a certain number of garbage bins is ready to be collected, the CC would compute the shortest path to all the garbage bins then sent it to the garbage collector agent to collect the garbage in an efficient manner. At the end of the trip, the garbage collector agent can rate the VAs that have involved in delivering the information to the CC. The rating system is created to avoid false data to be created by malicious VA. The higher the rating means the more trustable the data is while the lower rating data send by the VA would not be trusted. Thus, when a data packet sent by a VA that has low rating reached the CC will be discarded instantly and a retrack process will be taken to identify such VA, hence CC would be able to filter out the data that received by VAs. For an easier understanding of how data is passed, Figure 1 displays the scenario of how data is flows.

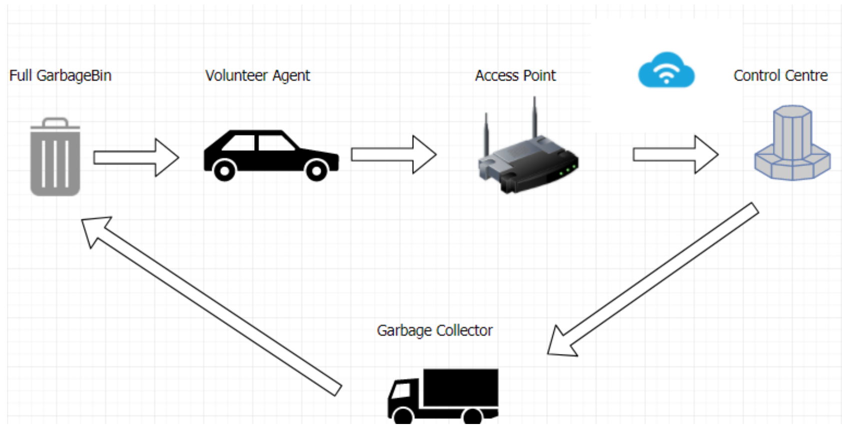

Figure 1. Scenario of how data pass over proposed architecture

3.2 Network Architecture

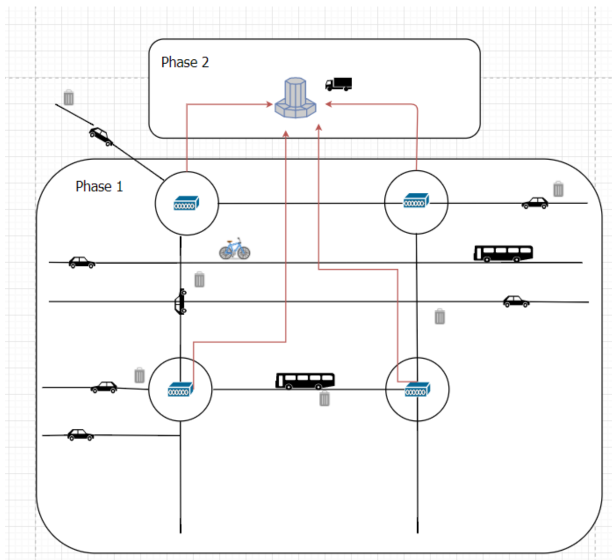

Figure 2. General two-tier architecture implementation

The network architecture of the proposed system is displayed in Figure 2. It is clear that our proposed architecture been separated into two phases. Phase 1 is mostly about collecting data from the access plane of the reported waste spots within a smart city, while phase 2 is involved in data processing and computing the shortest path for the Garbage Collector. The overviews phase 1 is that the smart garbage bin that is placed on the roadside to ease the collection process. The smart garbage bin that connected to the IoT network would then acquire the status of the garbage bin and generate waste Data packets. Waste data packets would then be gathered by any passing VA. VAs could be a smart public bus, smart cars, walking by or bicycles human with a hold of connected smart phone. The VAs would keep exchange this data to others VA (as a relay-hop) until one of the VAs could successfully deliver the data packets to the nearest available AP. Eventually, the AP would deliver the received waste data packets to the CC for further processing them to be used by the next phase2.

Thus, moving to the 2nd phase, which is the data processing. After receiving waste data packets from the recipient AP, the CC would then process the data packet and store them into the buffer; it is worth mentioning that the old data would be overwritten by the new data to maintain data storage. Afterwards, the optimal route as a solution will be computed and would then be sent to the garbage collector to collect garbage in an efficient way. When the garbage collector finishes collecting all the garbage it would then return to the CC and send packets back to the CC that it has finished collecting the garbage.

3.3 Data Transmission

In the proposed system, only the smart garbage bin will generate Data packets while the others component acts as an intermediate relay data points carrying packets until they reach the nearest AP. The data packets would have the garbage bin measurement level and, it's location. It is crucial highlighting that sending only a single data packet that carries this information; there will be high chances that the data packet would not reach to its destination whever this packet been dropped by any reason of network's failure. Therefore, duplicated packets would be sending out for a higher chance of the packet reaching the AP. This will be applied also by all relays VAs that intermediating the transmission process from the SGB to the distained AP. Thus, the VA needs to have a routing capability. As been suggested by (Azad, Rahman, Asyhari, & Pathan, 2017) a replication-based protocol will be used. As the name of the protocol suggests, it will replicate data packet whenever needed and increase the probability of the data packet to reach its destination. Lastly, a medium access control protocol would be needed on the entire component to transmit and receive the data packet and provide connectivity to the IoT wide-network.

3.4 Waste Collection Route Optimization

For optimizing the collection route, Dijkstra algorithm have been utilised to compute the optimum path for the entire garbage bins that are reported to be collected within a given smart city. Dijkstra algorithm is an algorithm that finds the shortest path between nodes in a given graph. It is also known as dynamic programming. Dijkstra is known as a greedy algorithm as it will not visit an edge that has already been visited, which is what we want in our case. Figure 3 shows the main steps of Dijkstra Algorithm in the form of pseudocode.

```
Initialise the cost of each node to infinity;nDistance
Initialise the cost of the source to zero;nPrevious
While there are still unknown nodes that are left in
the graph:
    Select the nodes with the lowest cost; b
    Mark the nodes as taken
    For each node;a which is adjacent to b
        dist = nDistance + edge (b,a)'s weight
        if dist is smaller than a's distance
            a's distance would be nDistance
            a's previous would be b
```

Figure 3. Dijkstra Pseudocode

3.4.1 Algorithm Flowchart

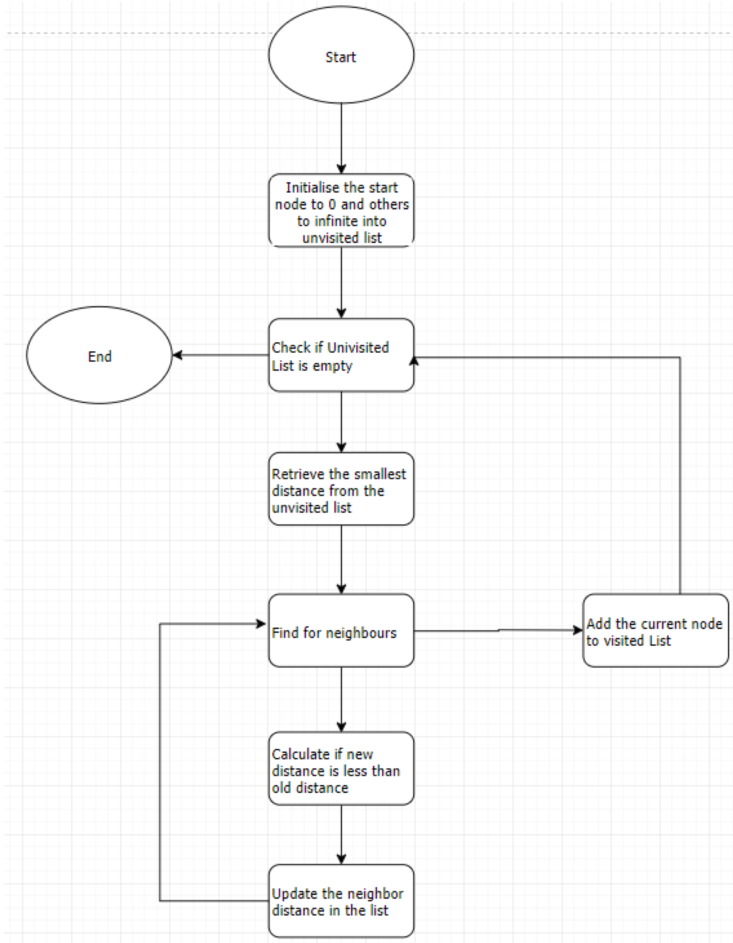

Figure 4. Waste Collection Flowchart using Dijkstra Algorithm

3.5 Simulation Setup

To show a proof of concept, we have conducted a simulation based on our proposed framework. The simulation was carried on using Netlogo a multi-agent programmable modelling environment, for more details of simulated model; readers can refer to Appendixes A1 and A2. The simulation consists of three main agents, which are the garbage bin, garbage truck and volunteer agents. We would first generate a graph with *n* number of vertices. In the graph, each turn in a road is a node while the edge is the roads. Measurements graphs have been generated to show the amount of cost and waste collected for each sequence. An output will also be included for a better view of the collected data. The cost and waste collected by the garbage truck would be extracted into a ".cvs" format from the Netlogo system.

Garbage Bin

The garbage bin has a capacity parameter with a maximum level of 100 waste units. In this simulation, 25 bins have been assigned to a city with a random amount of garbage level at the beginning stage of the simulation. When a garbage level is less than or equal to 50, the colour of the garbage bin would be grey, whilst the bin load getting more than 50 the colour will then change to yellow and finally when it is more than 80 the colour of the garbage bin will be set to red; indicating it is ready to be collected. We have annotated all these legends and values on the developed simulation GUI, which shows the amount of garbage bin to be monitored till it reaches full.

Garbage Truck

The garbage truck would start at the depot created in the simulation. The garbage truck would follow the optimum path that has been computed to collect the garbage bins that are almost full or already full. When the truck passes a bin with red colour, the colour of the garbage bin will be rested to grey colour and the level of the garbage bin will be set to zero. In our simulation, the amount of load that a truck can carry would be to a constant value of "1". Total cost per trip can be calculated by calculating the distance between all the nodes. The weight links between the garbage bins would act as the distance and we assume it takes 0.15 to reach from one garbage bin to another.

Volunteer Agent

A volunteer agent is created in this simulation to relay data to the CC. The VA has a rating percentage of 100; the percentage could change depending on the rating given by garbage truck. In our developed simulation, the VAs are classified into two kinds, genuine and fake agents. The bad volunteer agents would try to send fake data that leading to chang the original colour of the garbage bins to different colour, which indicating the status of the SGB. For instance, a yellow SGB the bad VA would change the colour to red. Once the garbage truck reaches the reported SGB and realise it is actually not full, the garbage truck then would reduces the rating of the VA. Accordingly, when the rating of the volunteer agent is less than 60, and the VA will be no longer able to send data peckets that would change the colour of the garbage bin, followed by a re-tracking process will be triggered by the CC. Hence, the VA will be no longer trusted, and data sent by the untrusted volunteer agent will not be taken into consideration as the agent will be removed from the crowd associated network. While the good VAs will keep sending genuine data of the SGBs and an insentive reword will be applied after a defined number of trusted reported garbage locations and volume around the smart city.

In netlogo an exist library called the *"nw:extension"*, we have utilised it to integrate Dijkstra algorithm to perform the shortest path calculation. It is imported noting that there is a limitation in using *"nw:extension"*, which only computes the shortest path between two nodes. This is insufficient in our case as we have lots of garbage bins, thus an improvising is needed. To begin, we first had to create all possible paths by using permutation process. From there onwards, we find the shortest path of each node to another node by using *"nw-turtles-weighted-path-to"*. *"Nw-turtles-weighted-path-to"* is a primitive in the *nw* extension, it returns the shortest path between the source and the target turtle. Finally, the path with the least weight needed will be returned to complete the path calculation. Figure 5 shows our improvised pseudocode of *"nw:turtles-on-weighted-path-to"*.

```
List of all possible path in a list
while list is not empty
    Assign the first node in the list to a variable
    Assign the second node in the list to a variable
    Get shortest path from first node to second node
    using nw:turtles-on-weighted-path-to
    Put the path in a list
     Remove first node from the path list
```

Figure 5. Improvised Pseudocode for in Netlogo

3.6 Evaluation

The evaluation will be done by comparing the cost of a collection vehicle and the total amount of garbage collected per sequence with the old setup where the garbage truck would collect every garbage bin at a scheduled time. Moreover, comparison will be done with bad VA, to see how an untrusted agent can affect the distance needed for the garbage truck to collect the reported bins. For simulation purposes, we will not ignore the data sent by untrusted volunteer agent to see how it affects the accumated cost. The old cost path will be also calculated by assuming the garbage truck will stop at each garbage bin as shown in Figure 6, without the existence of smart setup of SGB.

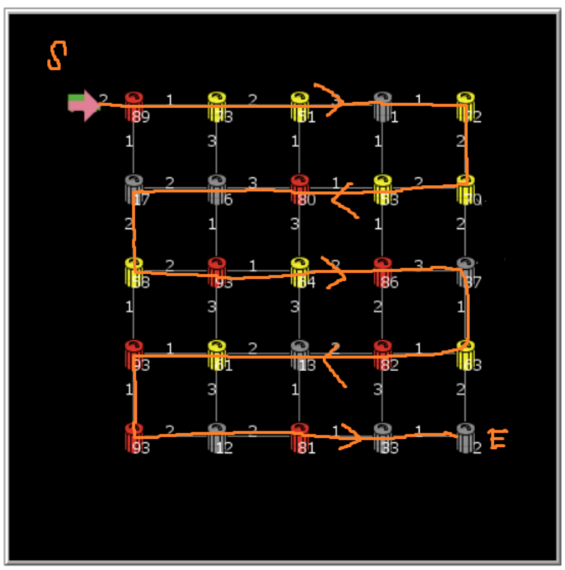

Figure 6. The path an old garbage truck will take

4. Results and Discussion

The implementation of the simulation with Netlogo for waste monitoring and optimal route selection for waste collection will be verified by running several simulations. The initial setup of the program will be having 25 bins located randomly in a city and a volunteer agent placed between two bins. All the bins will have a random level of garbage generated and their colour changes according to the provided condition. The VA can be a good volunteer agent or a bad volunteer agent. The monitor would provide the amount of garbage bin that is full. When the go button is clicked the *"ShortestPathNeeded"* monitor would show the amount of distance and time of the shortest path needed to collect all the red SGBs. Thus, the garbage truck will move towards allocated SGBs until the entire red garbage bins have been collected.

This can be seen in Figure 7, after finish collection, the garbage truck goes back to the depot and wait for six or more garbage bins that are ready for collection. For every tick (minute), a random value within a scale of 0 to 3 will be added into the garbage bin. Each time it finishes collecting the SGBs, the total cost as well as total amount of collected waste during that cycle would be captured and plotted on the respective graph to demonstrate the performance in real-time. When it detects six or more SGBs are full, a new vehicle will be sent out to collect them. This will continue until the "GO" button is pressed again. For the following simulation, this process will continue in three scenarios. Each scenario will run five times, each time the program will run within an average of 4-5 hours. The total collected data per time is around 1500 – 2000. The data collected during the 5 runs are exported to excel sheet and anova single factor is used to find the average of the five data samples. This is to validate and verify the data of our simulation and ensure reliability. Figure 7 displays when setup has been clicked, while Figure 8 demonstrates the simulation when the "GO" button has been clicked.

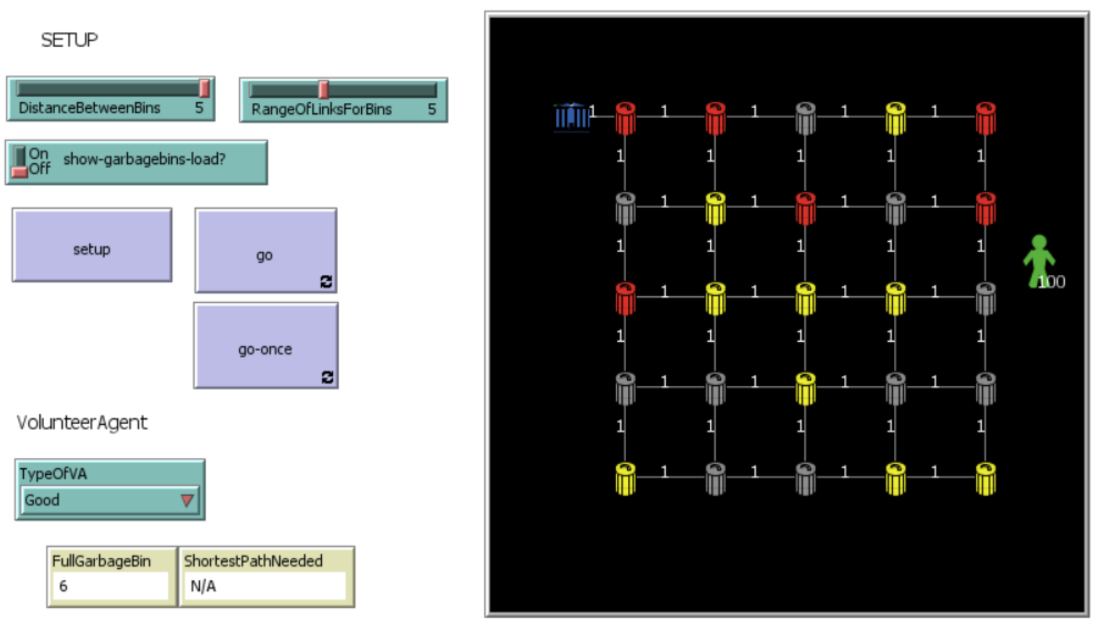

Figure 7. Initial setup for waste monitoring and collection in Netlogo

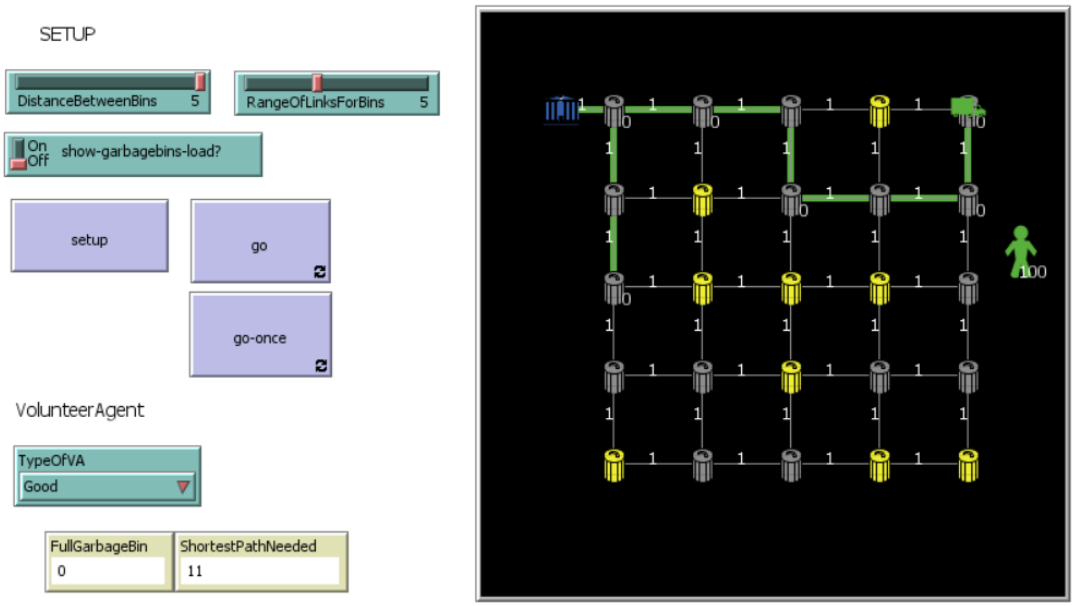

Figure 8. Optimal path for waste collection to 6 readied bins and colour changes when collected

The first scenario would be representing the most basic initial setup. This can be seen in Figure 6.

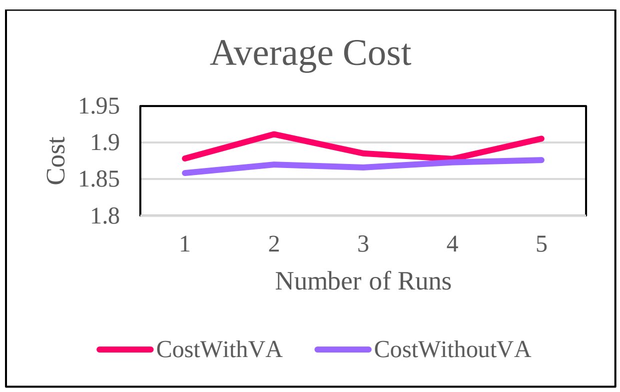

Figure 9. Average Cost for Scenario 1 in comparison with genuine and fake VAs

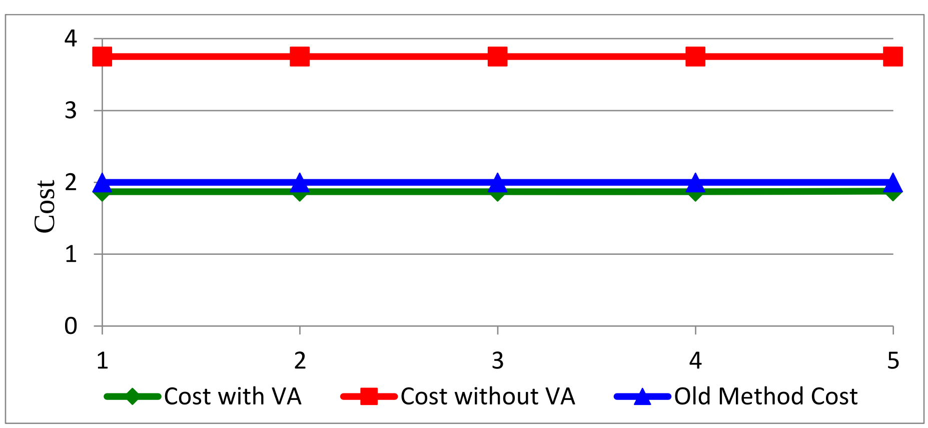

Figure 10. Average Cost for Scenario 1 in comparison with Old Method

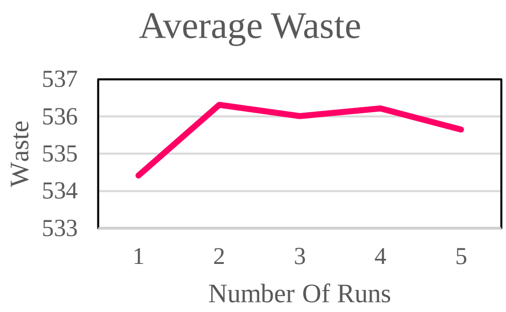

Figure 11. Average Waste for Scenario 1

Figure 12. Average Waste for Scenario 1 in comparison with Old Method

The next scenario will be increasing the number of garbage bins in the simulation. This can be seen in Figure13

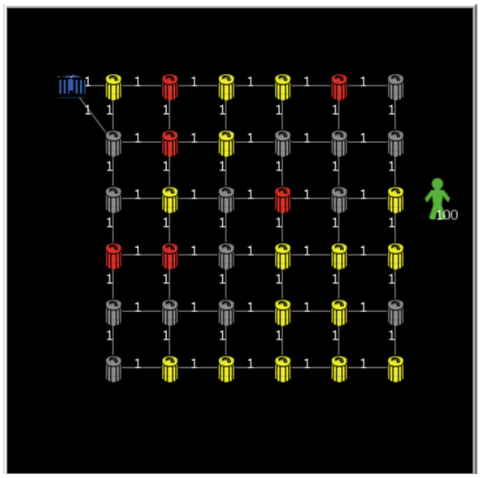

Figure 13. Scenario 2 with more garbage bin

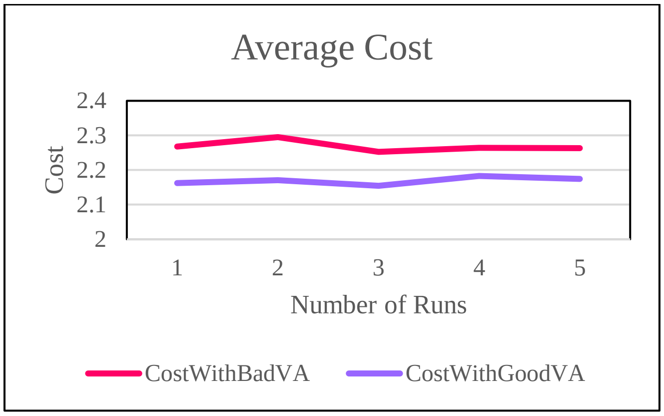

Figure 14. Average Cost for Scenario 2 in comparison with Good VA and bad VA

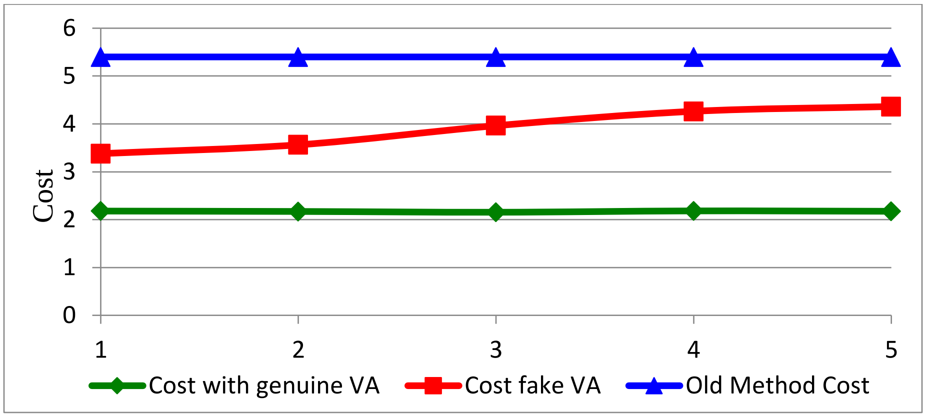

Figure 15. Average Cost for Scenario 2 in comparison with Old Method

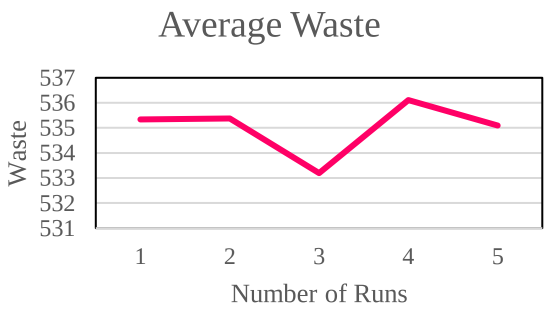

Figure 16. Average Waste for Scenario 2

Figure 17. Average Waste for Scenario 2 in comparison with Old Method

The final scenario consists of multiple paths available for the garbage truck to move, which can be seen in Figure 18.

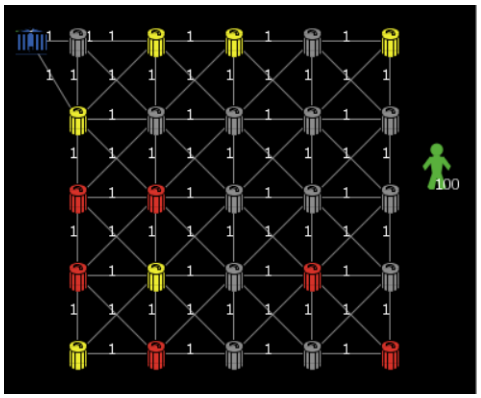

Figure 18. Scenario 3 with multiple paths

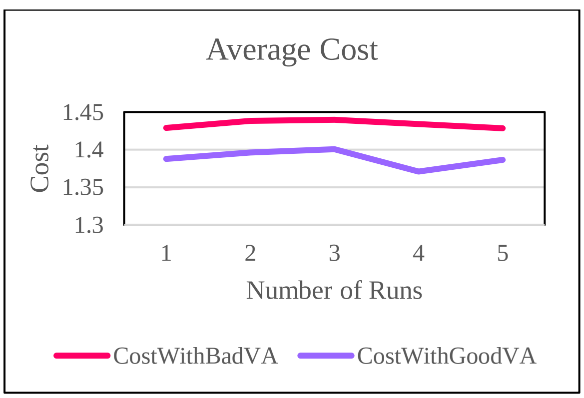

Figure 19. Average Cost for Scenario 3 in comparison with Good VA and bad VA

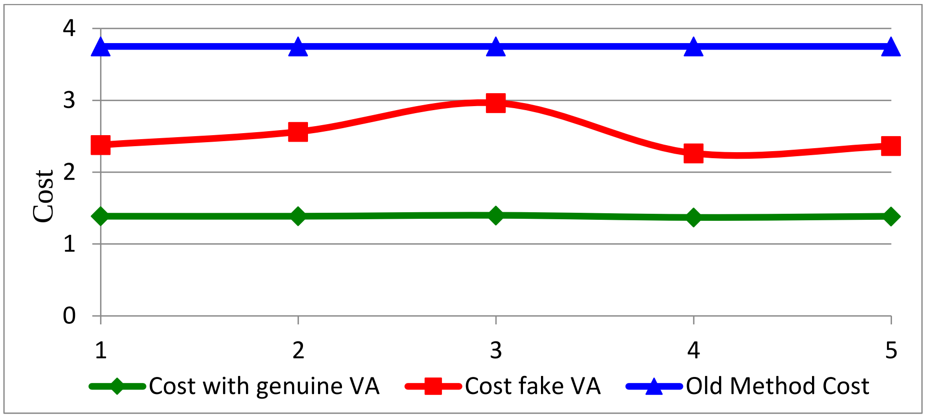

Figure 20. Average Cost for Scenario 3 in comparison with Old Method

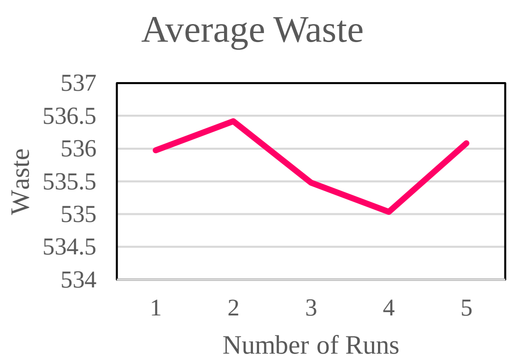

Figure 21. Average Cost for Scenario 3

From the performance analysis of the three simulated scenarios, it can be observed that our proposed solution could maintain less cost in collecting the entire SGBs, as compare to the old way of collection. Moreover, in terms of the amount of weight that a truck could carry, our proposed solution could maintain the garbage truck with an average weight without overloading the garbage as compare with the old way of collection. This is due to the fact that using Dijkstra algorithm, the garbage truck would obtain the computed shortest path to all SGBs beforehand is send out for collection. Thus, the cost needed to collect the garbage bins is substantially reduced as can be seen from the results collected out of three simulated scenarios in Figures 9, 10, 14, 15, 19, 20 and 21 accordingly. The other reason behind this improvement was that our proposed method only sent out garbage truck when more than six or more SGBs are full (red colour) within a given segment of the smart city. By doing so, the amount of garbage within each truck will no be overloaded and also reduces the time the SGB is left full. Form Figure 10, Figure 15 and Figure 20, when data packets sent by VAs are not filtered out, this will contribute negatively in increase the cost of travel of the garbage trucks as they have to go a further distance to collect fake reported SGBs. Thus, the results show how important is to filter out fake data when a fake VA is discovered, which has been achieved in our proposed method by applying the trust mechanism on each VA.

5. Conclusion and Future Work

In this chapter, we have proposed trust mechanism based on crowd associated architecture as it utilises crowd as part of the IoT network within the proposed architecture. A set of crowds (called volunteer agents) who collects data from smart garbage bins and delivers them to other volunteer agents in a multi-hope based communication till the data would reach its destination, which is the nearest access point that connected to the network infrastructure. The access point would then forward the data to the control centre. After receiving the data from various sources, at a later time, the control centre will compute an optimum path for the garbage collector in order to reduce cost of fuel as well as time in collecting garbage by reducing the travel distance. We have used Dijkstra algorithm to find the shortest path to all the reported SGBs as full. To proof the concept of our proposed architecture, we have conducted an extensive simulation with three scenarios, and it has been proofed that the proposed solution could indeed reduce the cost needed to collect SGBs within simulated smart city segment.

Many aspects can be improved in the proposed solution, which has been left for future work to be further considered. An option for future work is that applying a more developed mathematical model for route optimization such as modern meta-heuristic algorithms for fasting the process of finding more feasible solutions. In future work, we could also apply decision making algorithm to decide the amount/volume of garbage that each truck could collect base on the amount of garbage a truck can carry and total amount of garbage that been reported as full. Lastly, a decision algorithm that will filter out data sent by low-rating volunteer agents, so when computing optimum path, the system will proactively avoid taking the fake data into consideration.

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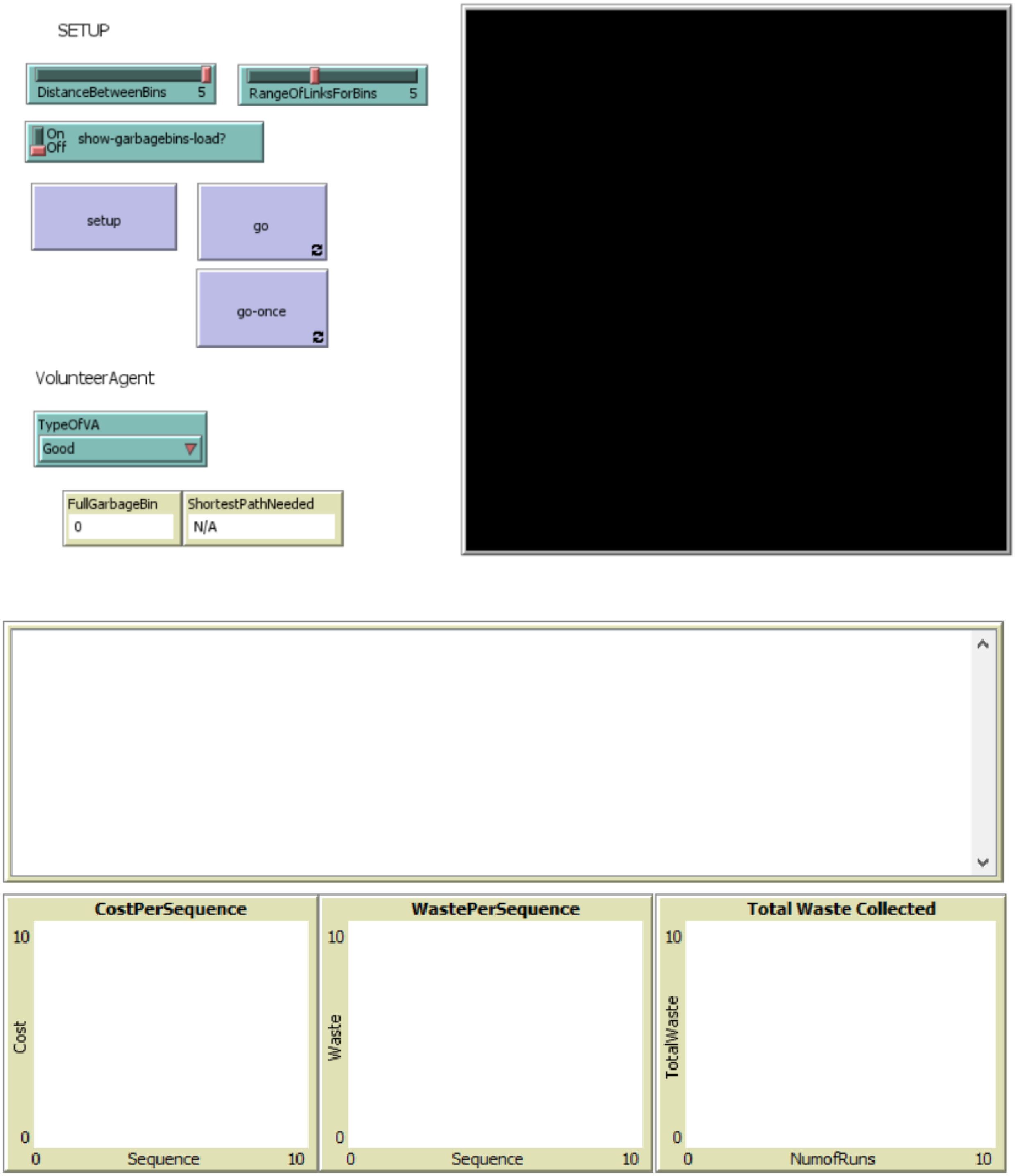
Appendices

A1: Internal Design Detail



A2: Diffinations of the developed simulation model.

DistanceBetweenBins - To determine the distance between the garbage bins, the lesser the range the more number of garbage bin will appear in the setup

RangeOfLinksForBins – To determine the range of links between bins, which means only bins within range of 5 will form a link.

Show-garbagebins-load? – If on you can see the amount of garbage in the bin if off you can only see colour

Setup – To display the agents in the world

Go – The simulation will loop forever until the go button is press again

Go-once – The simulation will only run once, to show how the program works

TypeOfVA – To change the kind of volunteer agent that will appear in the simulation

FullGarbageBin – A monitor that displays the amount of garbage bin that is full

ShortestPathNeeded – A monitor that display the length of shortest path

The output box will display the amount of waste, cost and the number of sequence.

To run the program, set the range of bin and links you want. Then click on setup to display the agents. Finally click on go or go-once to run the program.

Test Report

To test the correctness of the netlogo program, first open the program and select the parameter of the range between bins. Click on go-once to check if it shows the shortest path, click GO so that it runs forever. To collect the data for this project, the program is set to run for three to four hours. There might be times where the netlogo will output an error says the memory is too large. This is because, it has run for too long, thus restarting the program will solve the problem. Finally, the collected data will be exported in a “.csv” format to excel. The five data will be taken and calculate it’s average by using anova single factor.