Smart Waste Management

IoT – Solution Design

Submitted for

COMP6324 IoT Service Design and Engineering

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Revision History

Date	Author	Version	Change reference
03/03/2019	Ajinkya Biswas	0.0	Initial Version
04/03/2019	Daniel Hocking	0.1	Clean up and add Appendix A
18/03/2019	Ajinkya Biswas Elizaveta Efimova	0.2	Update requirements, add new software design diagram
19/03/2019	Zumar Ahmed	0.3	Add UAT section
20/03/2019	Daniel Hocking	0.4	Bring document back together into one cohesive whole, cleanup requirement
01/05/2019	Ajinkya Biswas Daniel Hocking Elizaveta Efimova Zumar Ahmed	1.0	Final Version

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1 Introduction

This document describes the high-level architecture for the 'City of ACMI faces a problem with waste collection' project. The requirement is to capture the waste level from waste bins of residential houses and provide information on waste level that can help city council operators to schedule waste collection more efficiently. From the collected data, reports can be created that will help plan future waste management and schedule waste collection. The reports will be a part of a web application and mobile application. One mobile app will be available for garbage truck drivers which will show the bins on map and their waste level in real time and an optimized route to collect the filled bins. Another mobile application used by residents will be to report the waste level without having the IoT device installed in the bins.

This document outlines all the components/modules involved in developing the solution and how they interact with each other.

2 Purpose/Audience

The audience for this document is the industry mentor, technological mentor, project evaluators and development team for the project. It provides guidance to the developers on construction of code and storage mechanism for related data. The mentors can verify the design to see if all the functionalities are covered as part of the project.

3 Goals and Objectives

The primary goal of the project is to reduce inefficiencies in the residential waste collection process, residents should wait less time for full bins to be collected and garbage collectors should waste less time collecting nearly empty bins.

To achieve the primary goal the objective of the project is to capture waste levels from a bin with the help of a Raspberry Pi 3 Model B+ and ultrasound proximity sensors, connect it to Amazon AWS and build supporting web and mobile applications.

4 Requirements

4.1 Functional Requirements

- The current level of fullness of resident's garbage bins should be constantly monitored and the data should be reported back to a central repository.
- The current level of fullness of resident's garbage bins can be manually reported by the resident through a mobile app if the automatic system is not being used or as a backup to the automatic system.
- When collection has been scheduled for a resident's garbage bin, they should be notified ahead of time so they can ensure their bin is available to collect.
- Central repository where data from the IoT devices can be collated together and both current and historical data can be recorded.
- Garbage collectors should have visibility of how much garbage is in a bin without having to stop and check a bin, they should be directed efficiently to bins that need to be collected.
- Operational management should know what the current system status is regarding bin fullness and be able to look back on historical data about garbage collection.

4.2 Non-functional Requirements

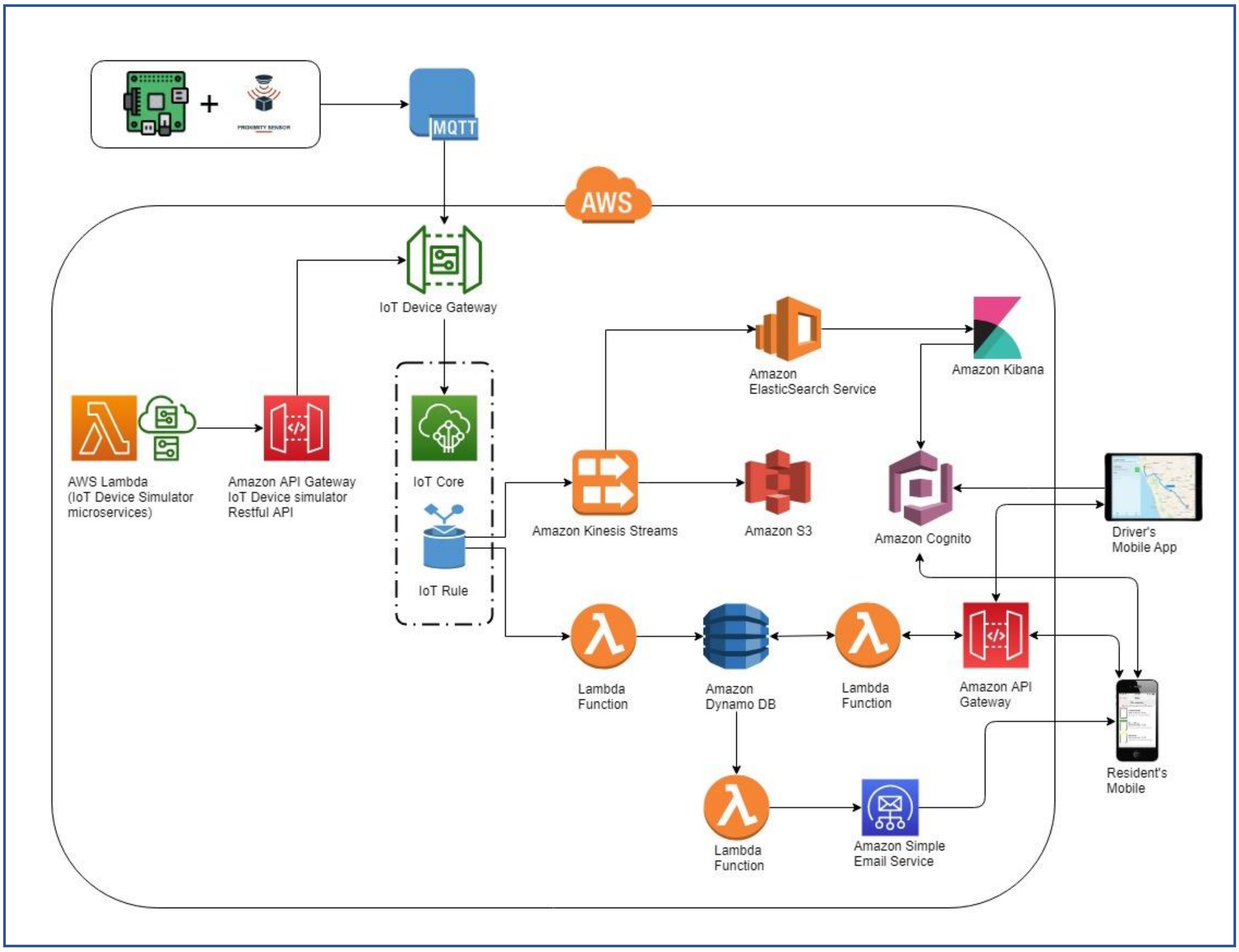
- An IoT device will be attached to the underside of the lid of resident's garbage bins
- The prototype version of the IoT device will make use of a Raspberry Pi 3 Model B+ and will have several ultrasonic sensors attached to it to monitor the bin fullness level.
- The IoT device will have more than one ultrasonic sensor spaced out so that an accurate estimate of the bins true fullness level can be ascertained.
- The IoT device should not cost more than $100 when the retail version is launched.
- The IoT device will communicate with the central system using Wi-Fi, and the MQTT protocol.
- A mobile app will be available to residents, this app will be useable from their phones and will be free to users.
- The mobile app will allow residents to self-report their garbage bins fullness level, for simplicities sake it will only allow residents to report when collection is required, and not require constant updates on fullness.
- The mobile app will provide notifications to resident's when collection has been scheduled, this should occur at least 24 hours ahead of collection to give residents warning to ensure the bin is available to collect.
- The central repository where data is stored will make use of Amazon Web Services.
- AWS IoT core will be used to handle communication with IoT devices.
- Amazon DynamoDB will be used to store the current data and Amazon S3 will be used to store all historical data.
- Data from AWS DynamoDB will be used to compute the garbage levels of the bins from received sensor data, then compute the geographical location from the bin's identification number.
- Data from Amazon S3 will be used for analytics to give an overview/dashboard to the operators.
- To provide a map view of the bins and the garbage levels, we will create a web app and use Google-API to show the bins locations.

5 Deployment Design

The following diagram shows the overall solution components and how the objects, devices, communications network and software platforms are deployed.

6 Software Design

The following diagram shows the various software components involved and the high-level architecture of the application.



7 User Acceptance Testing

7.1 Get data from sensors to Raspberry Pi

Purpose	Getting data from sensors and sending the output to Raspberry Pi
Preconditions	Sensor connected to Raspberry PI
Test data	Bin level: 40%
Process Steps	1. Sensor connected to the input pin of Raspberry Pi through wire. 2. Sensor will sense data and send it to Raspberry Pi. 3. Raspberry Pi will validate data.
Post condition	Data should be received by Raspberry PI

7.2 Sending data from bin to the cloud through Raspberry Pi

Purpose	Publish data from Raspberry Pi to AWS
Preconditions	Raspberry Pi connected to internet
Test data	Location: UNSW Bin level: 40%
Process Steps	1. Raspberry Pi gets data from sensors. 2. Raspberry Pi publishes data of sensors and location to AWS every 10 minutes. 3. Raspberry Pi gets response from AWS.
Post condition	Data should be published to AWS

7.3 Sending data from app to AWS by resident

Purpose	Publish data from client app to the internet
Preconditions	User login with correct credentials
Test data	Username: abc@unsw.edu.au Password: 123456
Process Steps	1. Login to application. 2. Resident chooses the trash level. 3. Resident taps on submit button. 4. Application sends bin level data to AWS core 5. Application shows success response.
Post condition	Data should be published to AWS
Exception flow	The application should display error if the resident has not selected trash level

7.4 Getting optimized route for collecting bins

Purpose	To get the optimised route of full bins
Preconditions	User login with correct credentials
Test data	Username: abc@unsw.edu.au Password: 123456
Process Steps	1. User is on the home screen. 2. User selects location. 3. User selects "Optimised route" 4. Optimised route is displayed on maps.
Post condition	The optimised route for garbage collection must be displayed on maps.

8 Appendix A – Planning notes

8.1 Primary Stakeholders

- **Residents** of the council area who have waste that needs to be disposed of, this is usually done by sorting waste into one or more garbage bins based on type, then at the appropriate time moving the bin to the side of the street, so that it can be collected on a static schedule
- **Garbage collectors** whose job is to drive a garbage truck around a fixed route and collect the garbage from all bins along the way
- **Operational management** who are responsible for ensuring that garbage is collected and disposed of in a timely manner, they make the decisions on how garbage collection should take place, and determine if it is being done effectively

8.2 Key Challenges

- Full bins are not emptied until day of collection (residents)
- Easy to forget to move bin to kerb and then have to wait another week (residents)
- Stopping to collect empty or nearly empty bins wasting time (garbage collectors)
- Inefficient driver route (garbage collectors, operational management)
- Increased cost due to inefficiencies (operational management)
- Low visibility of waste levels impeding planning (operational management)
- Lots of general waste and low levels of recycling (operational management)

8.3 Challenges, Solutions, Technology, Benefits, Risks

	Challenges	Solutions	Technology	Benefits	Risks
Residents	(1) Full bins are not emptied until day of collection (2) Easy to forget to move bin to kerb and then have to wait another week (3) Inefficiencies mean wasted tax dollars (4) Low levels of recycling lead to negative environmental outcomes (5) Collection patterns don't always match bin usage patterns e.g. Green waste bins usually aren't used that often, but when they are, they are often inadequate	(1) Monitor bin fullness using sensors, report this information so that bin collection can be scheduled before it is full (2) App could be used to report when bin is full/nearly full (3) App could provide notifications on when to take bin down to the kerb (4) With detailed information about bin fullness and location could plan efficient bin collection (5) An app could allow for easy lookup of what can go into recycling (6) An app could gamify the recycling process, could even make it competitive on a neighborhood level (7) Computer vision to determine where waste should go (8) Sensors could prevent unneeded collections (9) Large collections could be scheduled through the app	(1) An IoT device with network access capabilities, ideally it would also have GPS, but basic location information can be found via the network, in addition it needs some kind of fullness sensor: infrared, radar, weight, touch (2) App for mobile devices would need to include iOS and Android, depending on budget it may be better to make a responsive web app and make a simple wrapper for specific devices (3) Would need a server backend to the app that could store data and use it to create efficient collection routes, backend could use AWS or similar cloud solution (4) Combined with (2) above would need a database to store details about what items go in what bin (5) Cloud providers like AWS have computer vision API that could aid in this	(1) Automated tracking of bin fullness reduces need for user input, convenient, less chance of human error (2) Cheap to scale after initial development, can be improved easily over time, as reliable as user	(1) Expensive equipment and issue of installing in every bin, could be stolen if its valuable, could break, battery go flat, malfunction and give wrong data, if network access provided by user this may be unreliable or non-existent (2) Requires user input to work, tedious, big upfront development

Collectors	(1) Stopping to collect empty or nearly empty bins wasting time (2) Inefficient driver route	(1) Sensors provide real-time visibility on bin fullness (2) Could integrate with an AR (augmented reality) HUD in the truck to indicate fullness of bins (3) Could add a light to the bin which would flash when truck gets close if the bin needs collection (4) Information about fullness of bins can be returned to a central system that can handle efficient route planning	(1) Either a HUD in truck or simply a screen to display the location of bins in surrounding area and indicate their fullness, if AR based rather than simply showing on a map then would require significant computer vision to identify bins in surrounding area, cameras on truck (2) The bin based IoT device could include a visible light that can be activated remotely by the truck when it approaches the area if collection is required	(1) Very easy for truck driver to identify bins requiring collection and how they are positioned in the surrounding area (2) Provides similar benefits to (3) however does require line of sight with bins, simpler to implement	(1) Requires expensive equipment in the truck, difficult computer vision task to have it working reliably (2) In some environments this will have a short effective range, increased complexity and battery drain on bin-based device
Management	(1) Increased cost due to inefficiencies (2) Low visibility of waste levels impeding planning (3) Lots of general waste and low levels of recycling	(1) Sensor provide real-time visibility on bin fullness which reduces inefficiencies (2) Sensor provide real-time visibility on bin fullness, this data can also be stored and provide additional historical reference for planning purposes (3) Real-time visibility and increased data could allow for improvements to be made in recycling			