Smart Garbage Management

Team **sddecc18-08**

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http://sddec18-08.sd.ece.iastate.edu/

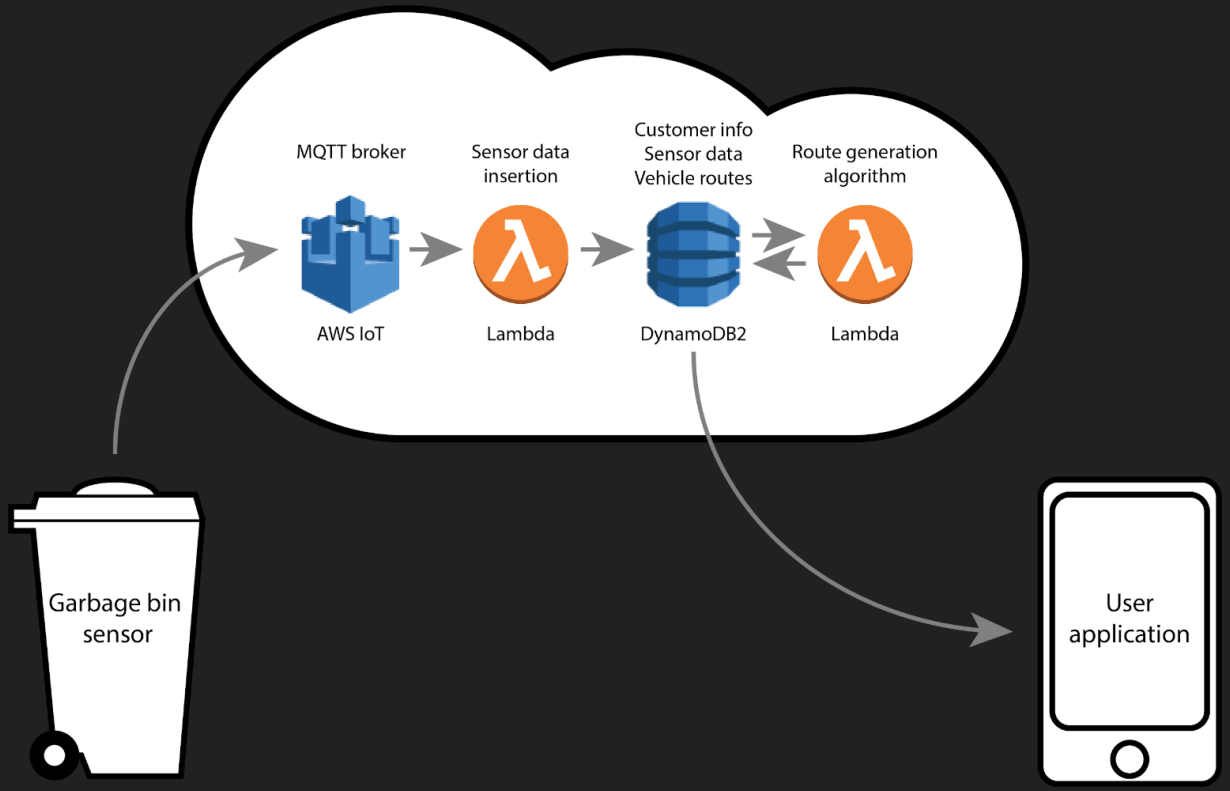
Problem

- 254 million tons of garbage created in the USA in 2013
- Garbage routing is static and does not factor dynamic customer behavior
  - Does not account for an individual customer’s needs
  - Cannot accurately predict when a truck will become full

Solution

- Smart garbage bin
  - Measures garbage height & weight and uploads to cloud
- Smart routing
  - Creates efficient collection routes based on collected data
- Resident and waste management applications
  - Allows waste management to view smart routes
  - Gives customers insight into their waste disposal habits

Basic Modules



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Functional Requirements

- Trash bin device must determine approximate weight and height of contents
- Garbage sensor communication
  - Secure
  - Verifiable
  - Guaranteed to reach cloud
- Collection routes must use less fuel than a naive route
- Generated routes will accurately predict when garbage trucks will be filled

Non-functional Requirements

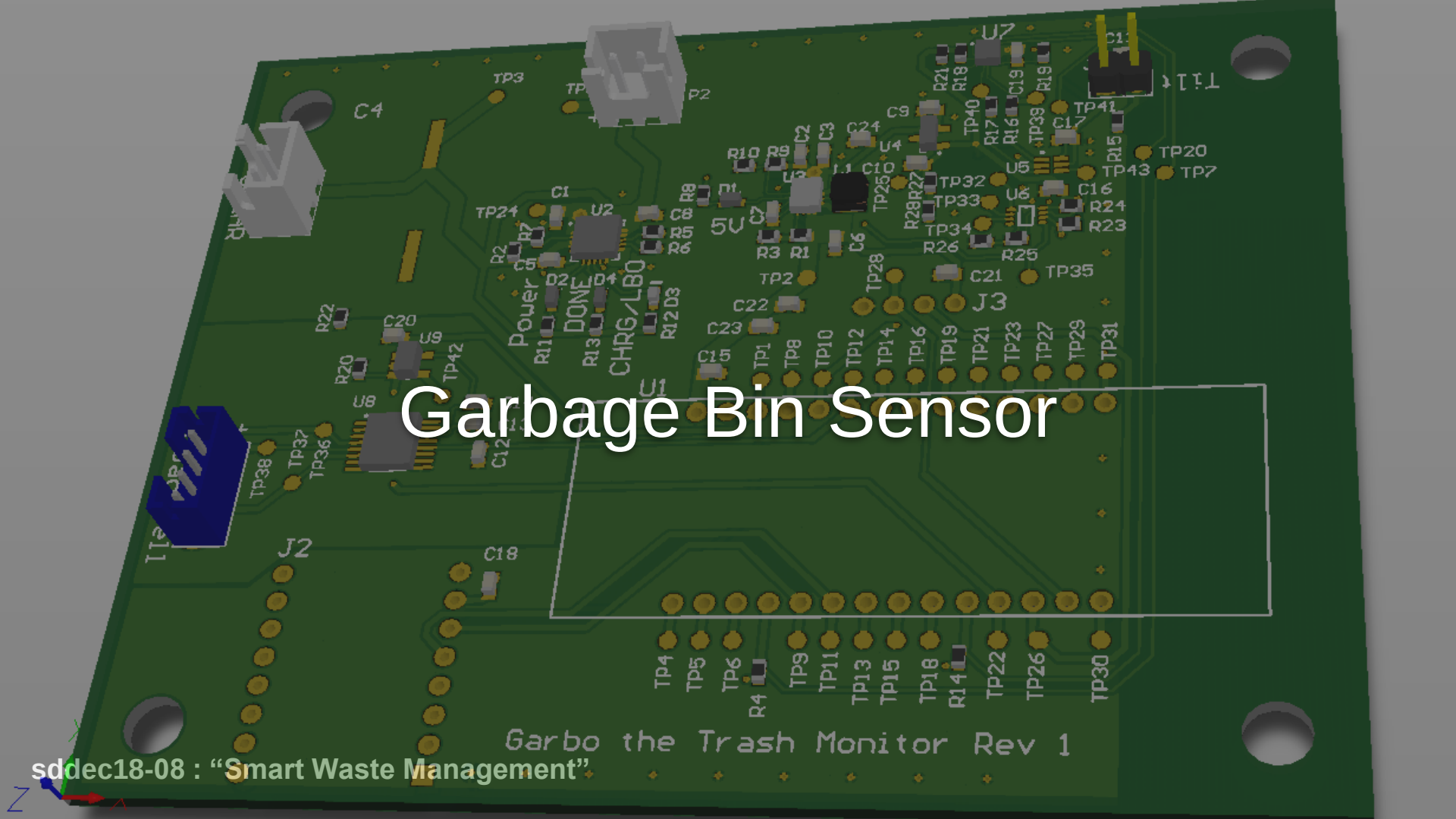
- Scalability
  - Capable of incorporating a large number of garbage sensors
- Heterogeneity
  - Able to seamlessly integrate multiple waste management clients into the service
- Usability
  - Product simple to use and install
- Data security
  - All communication must use end to end encryption
  - Protect user data

Constraints

- Residents are not used to charging their garbage cans
  - High capacity battery
  - Efficient power usage
  - Solar panels
- Cost
  - Residents
    - Not willing to spend substantially more money on waste management
  - Waste Management Companies
    - Cost of implementation must be reasonable compared to return on investment

Potential Risks

- Data Leaks
  - Network vulnerabilities
  - Data center breaches
- Defective garbage sensors
  - Damaged sensors
  - Power loss
- Stolen garbage bins
- Consumer misuse
  - Device tampering


Garbage Bin Sensor
Garbo the Trash Monitor Rev 1

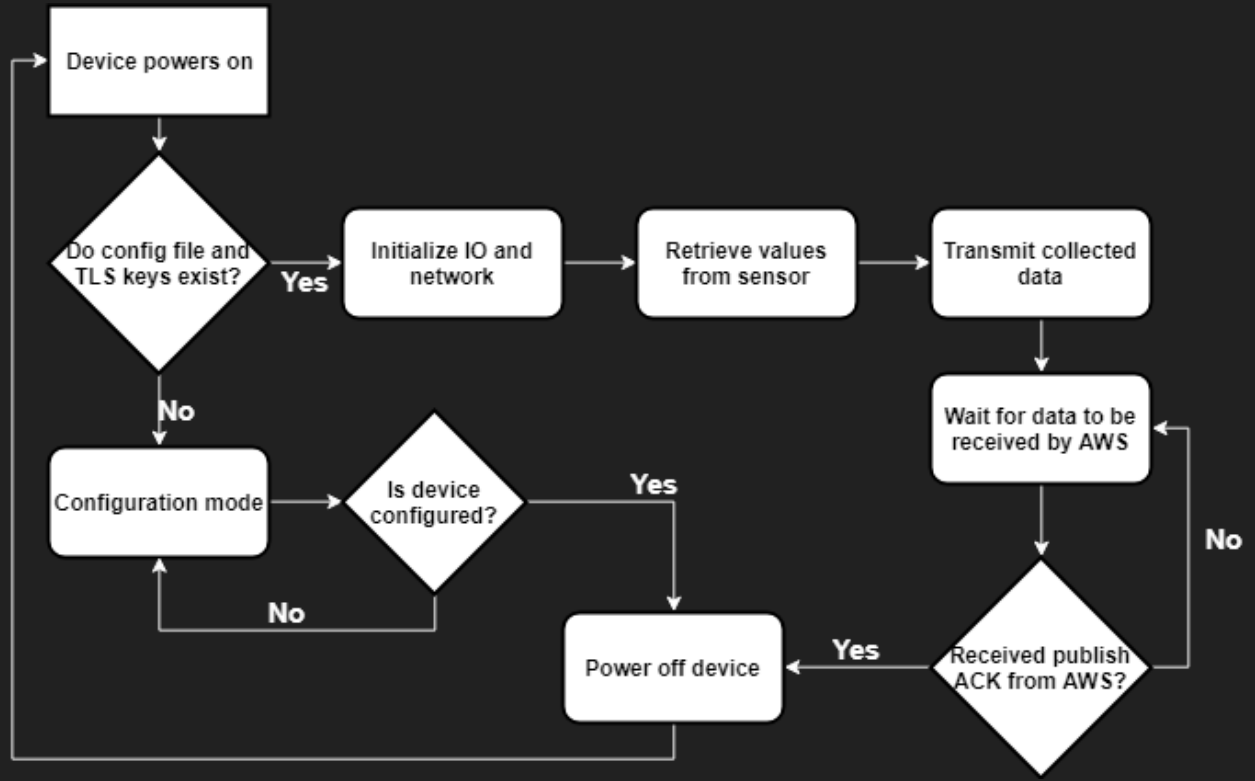
Sensor Considerations

- Low power
  - Standalone device
  - Must be able to sustain operability for several weeks without charge
- Low cost
  - Device cost must be feasible to deploy
- I/O Limits
  - Limited number of GPIO pins on Pycom FiPy development board
- Durability
  - Adhere to Outdoor/Automotive temperature and vibration standards

Sensor Overview

- Retrofittable to lid of standard residential garbage containers
  - Lower installation cost
- Lid movement wakes device from low power sleep mode
- Powered by lithium cell with multiple charging options
  - Charge over USB for programming and device configuration
  - Charges via solar cell on top of garbage container
- Interfaces with load cell attached to bottom of container
  - Measures weight, a critical metric for garbage collection but complicates installation
- Wirelessly transmits to Amazon Web Services' Internet of Things Core

Sensor State Diagram



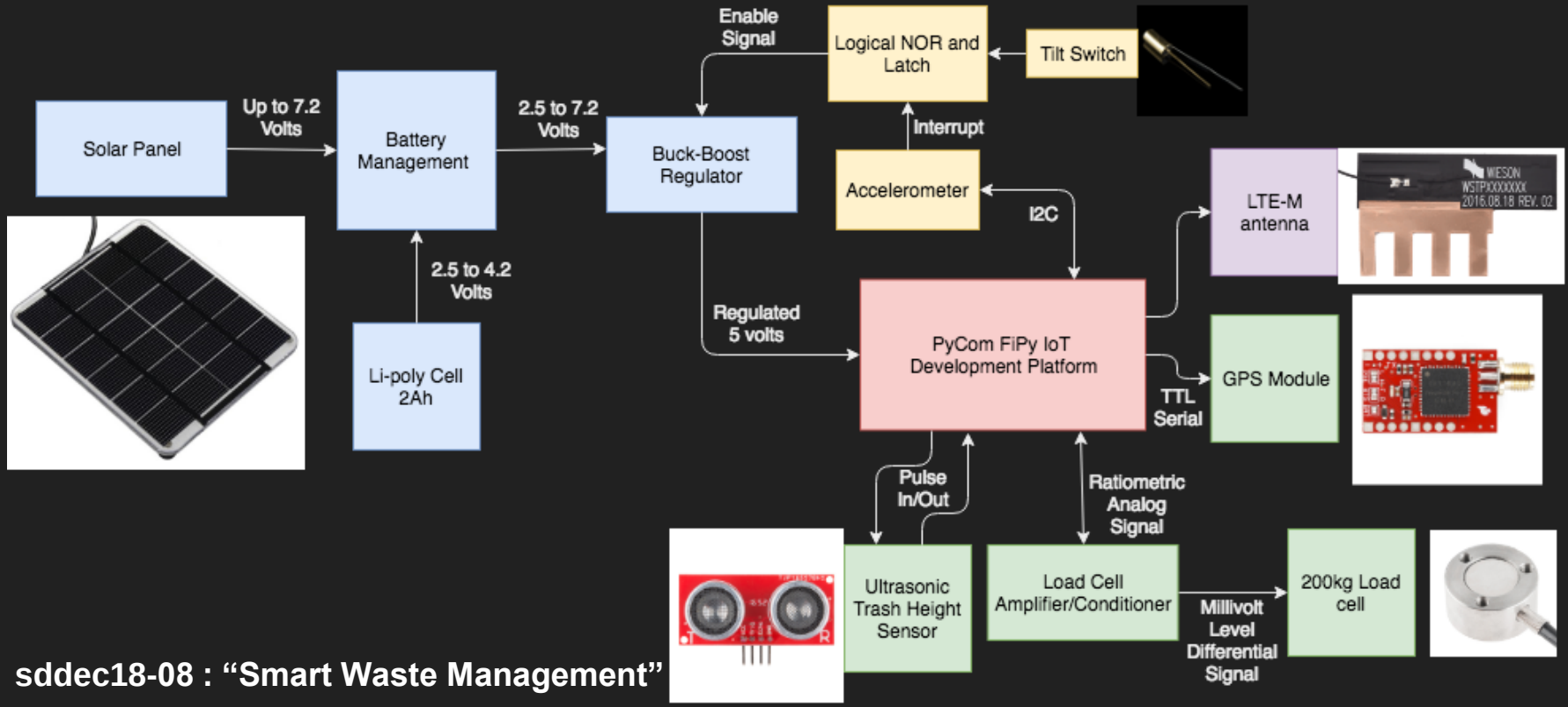
Sensor Communication

- Communication layer
  - LTE CAT M1
    - Low power characteristics satisfies energy efficiency requirements
    - Features include long range communication and high building penetration
- Transport layer
  - Message Queuing Telemetry Transport (MQTT)
    - Encrypted over Transport Layer Security (TLS) connection
    - Sends JSON packet containing location, trash measurements, and measurement time
    - Brokered by AWS IoT Core
      - Invokes Lambda function that places measurements in DynamoDB table

Sensor Circuit Board Design

- MCP73871 battery charger
  - Used to charge lithium cell and power board via solar or USB power
- TPS63701 buck-boost switched mode power supply
  - Regulates battery or MCP73871 load voltage to 5 volts for Pycom FiPy
- Custom ultra-low power sleep mode
  - Accelerometer interrupt or tilt switch detects lid movement and sets TinyLogic latch
  - The latch enables switched mode power supply
  - FiPy board re-enters sleep mode by clearing the latch
- Headers for GPS, ultrasonic sensor, and Pycom FiPy development board
- Manufactured using low-cost two-layer 6/6 mil 1 oz copper board process

Sensor Hardware System Diagram



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Sensor Testing

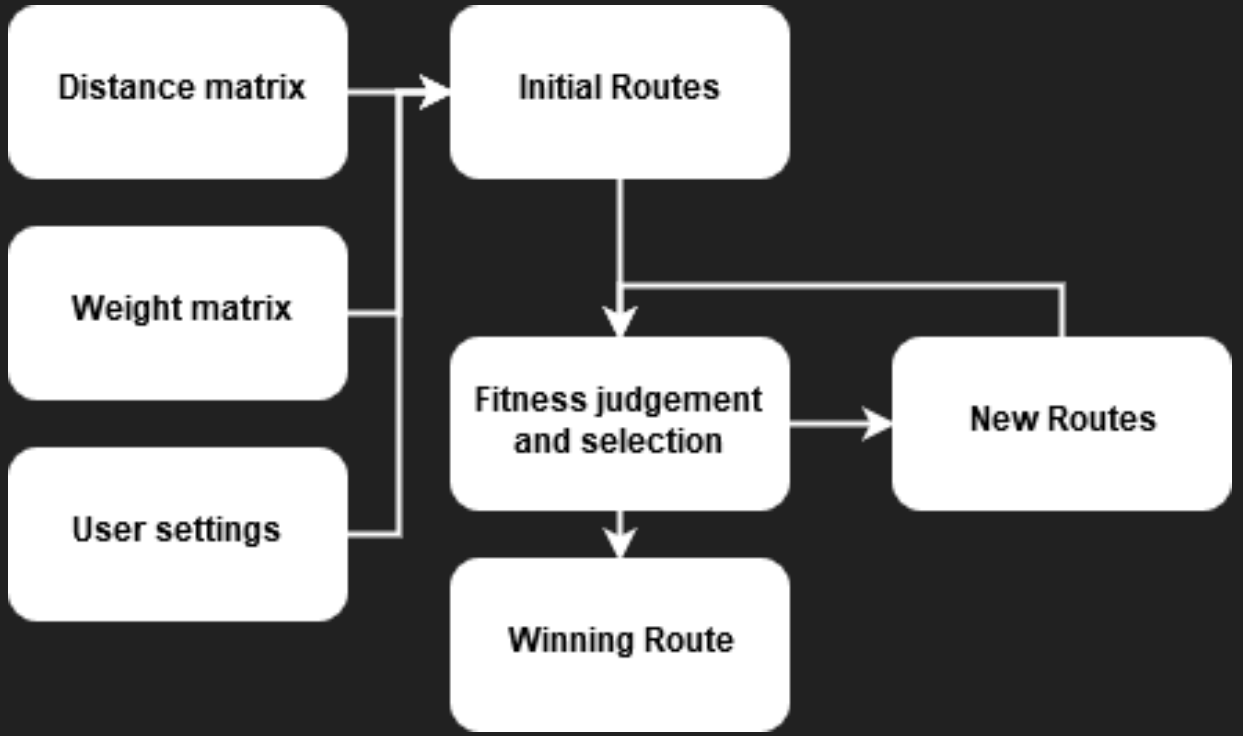
- Board testing
  - Tested for shorts or faults in manufacturing
  - Verified battery manager and voltage regulator worked correctly
  - Ensured sleep circuit behaved as intended
- Power testing
  - Calculated by measuring active and sleep current consumptions
  - Results estimated a lifetime of 7 to 11 weeks off 2,000 mAh battery
- Software testing
  - Individually tested software modules that interacted each sensor
- Integration testing
  - Ensured final software ran on Pycom FiPy board when attached to prototype
  - Tested communication from garbage sensor to AWS IoT Core

Vehicle Routing

Routing

- Model
  - Select garbage bins that are full enough to warrant pick up
  - Use those bins as nodes in a vehicle routing program
  - Use a genetic algorithm to build a route in that solves the vehicle routing problem
- Genetic Algorithm
  - Builds a population of random routes
  - Repeatedly builds new generations of routes through selection and merging
  - After a user set number of generations, select the best available routes

Routing


Distance matrix
Weight matrix
User settings
Initial Routes
Fitness judgement and selection
New Routes
Winning Route

Routing Testing

All tests used a population of 200 chromosomes, ran for 25 generations, and were tested 1000 times

Test 1 (Simple Human Solvable Traveling VRP): 100%

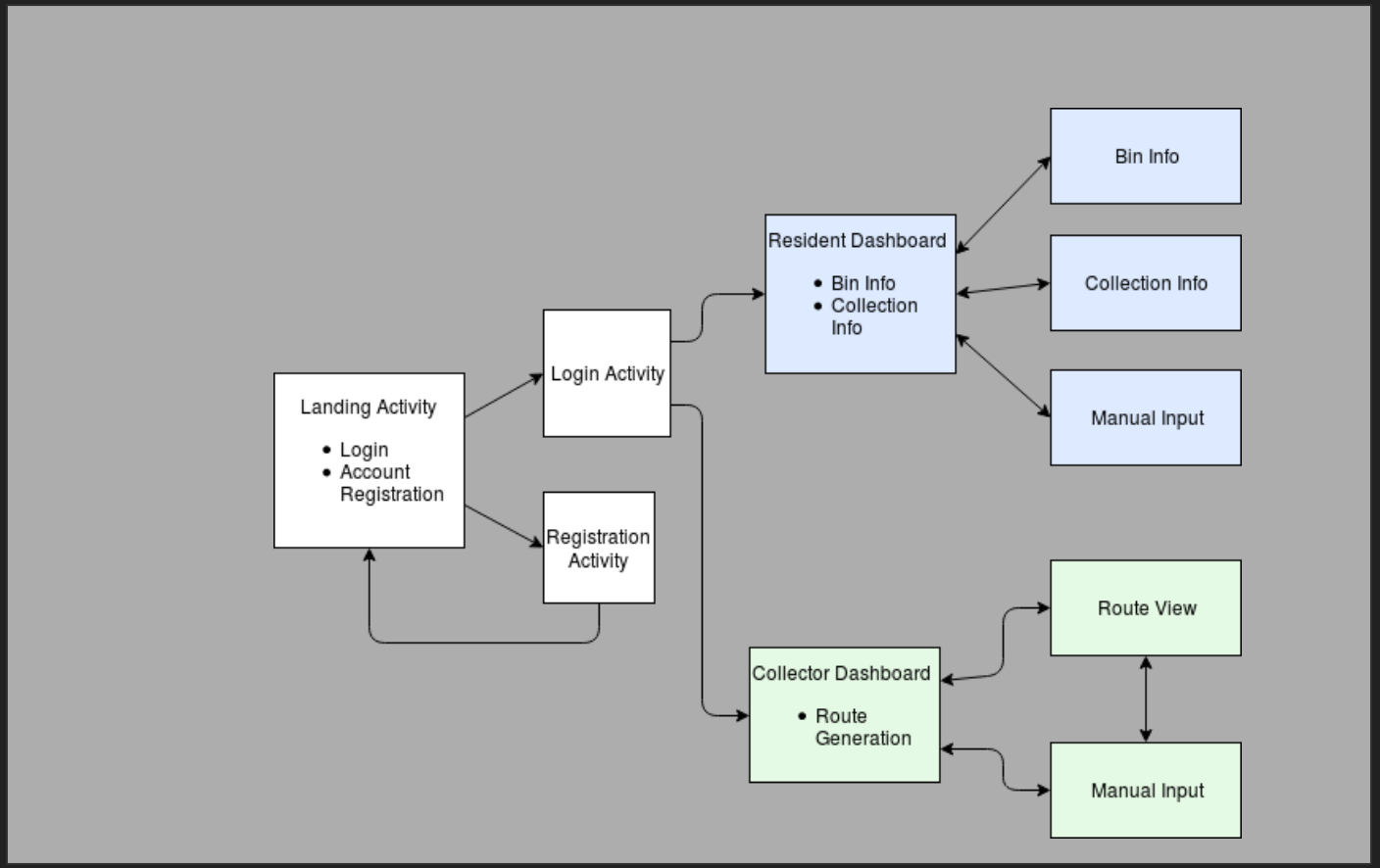
Test 2 (One Linear Cluster, One Truck): 100%

Test 3 (Two Linear Clusters, Two Trucks): 98.7%

Mobile Application

Mobile Application

- Bin Monitoring
- Routing Interface
- Resident - Collector communication



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Validation

- Garbage bin sensor
  - Ensured power demands would satisfy lifetime requirements
  - Tested ultrasonic sensor and load cell for accuracy
  - Verified data was measured and stored in database
- Vehicle routing algorithm
  - TODO
- User application
  - TODO

Current Project Status

- Spring 2018 Milestones
  - Integrated Sensor Testing
  - Communications Testing
  - Homeowner App Frame
  - Clustering Tests
- Fall 2018 Milestones
  - Completed garbage sensor prototype with full AWS integration
- TODO

Future Work

- Create second garbage sensor prototype
  - Focus on continuing to lower power constraints and lower costs
  - Integrate MCU, wireless modem, GPS, and ultrasonic sensor onto single board
  - Finalize load cell fixture and board enclosure
  - Weatherproofing board and conducting vibration testing
- Load testing AWS services
- TODO

Thank you

Individual Responsibilities and Contributions

Robert: AWS Lambda Functions and OSM Route Creation.

Colin: Garbage sensor design and software development

Nicholas: Researching and assisting with Mobile Application

Samuel: Routing and Clustering Logic

Steven: Component integration, board design, and power management

Brendan: Mobile Application

Appendix: Project Costs

Hardware Prototype	$140/Device
Cellular Subscription	$16/Year/Device
Software Backend Costs	$480/Year/Municipality

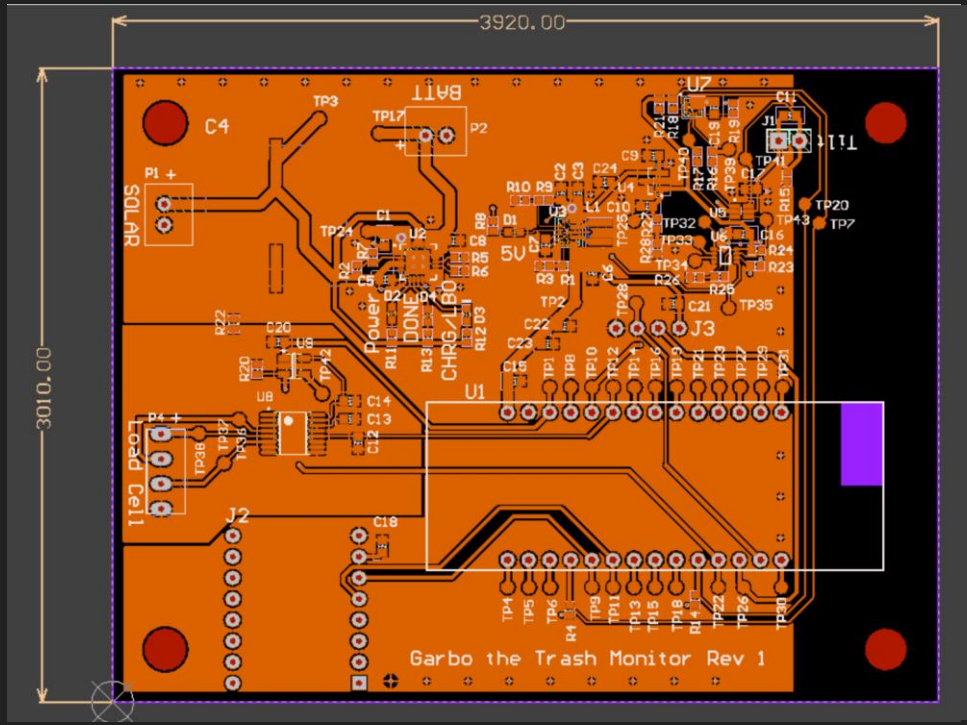
Appendix: Garbage Sensor Power Test Results

Minimum consumption percentage	17.16 mAh / week
Maximum consumption percentage	22.2 mAh / week
Maximum estimated lifetime	5.8 weeks
Minimum estimated lifetime	4.5 weeks

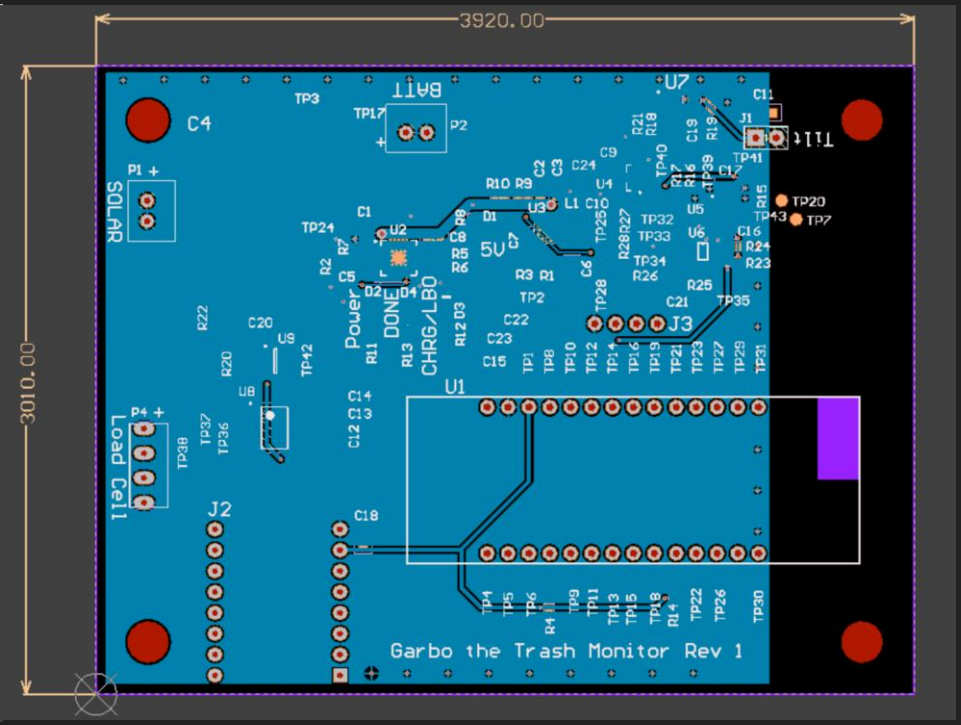
Appendix: Circuit Board Schematic

Appendix: Circuit Board Details

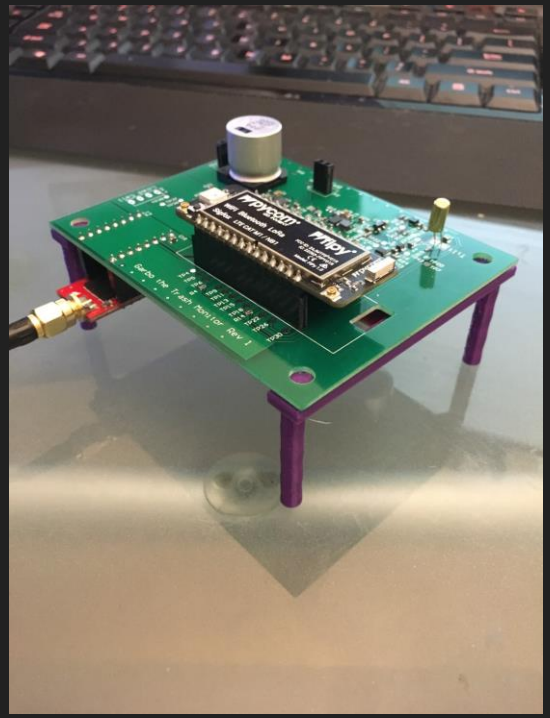
Top Layer



Bottom Layer



Appendix: Garbage Sensor Prototype



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