SPL

Smart Parking Lot

Winter Quarter Review

Project Website: andrewhlu.com/spl

Problem

Drivers spend too much time in parking lots trying to find an open space. Many parking lots only have per-floor capacity indicators, and existing solutions are prohibitively expensive.

What if we could utilize low-cost sensors and a companion application to navigate drivers to empty parking spots faster, at a low cost to facility owners?

Smart Parking Lot Overview

The goal is to design a smart parking lot that will direct drivers to the nearest open parking space on campus in an efficient, accurate and clean manner.

We accomplish this using:

- Small, inexpensive parking lot sensors with long-distance and low-power transmission
- Modern, open-source, and cloud-based software solutions
- Easy-to-use mobile interfaces

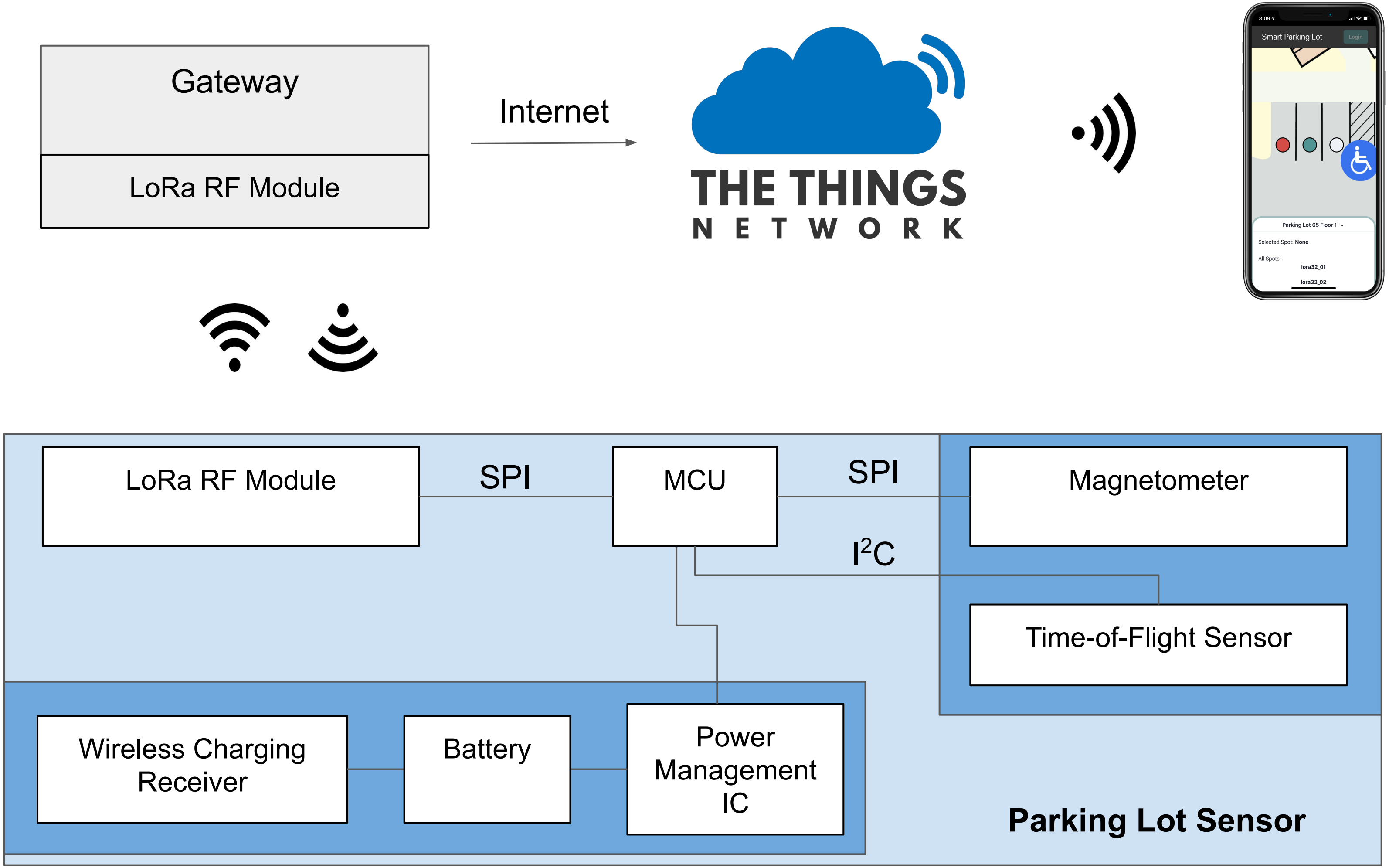
Roles

Andrew Lu
Gateway Application
Web Application Frontend and Backend

Luyao Han
Sensor Firmware
PCB Design
Wireless Charging

Finn Linderman
Wireless Communication
Power Management

Jun Cho
LoRa Communication
The Things Network Integration


Gateway
LoRa RF Module
Internet
THE THINGS NETWORK
Smart Parking Lot
Login
Parking Lot 65 Floor 1
Selected Spot: None
All Spots:
lora32_01
lora32_02
LoRa RF Module
SPI
MCU
SPI
Magnetometer
I²C
Time-of-Flight Sensor
Wireless Charging Receiver
Battery
Power Management IC
Parking Lot Sensor

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Hardware Progress

Hardware Design

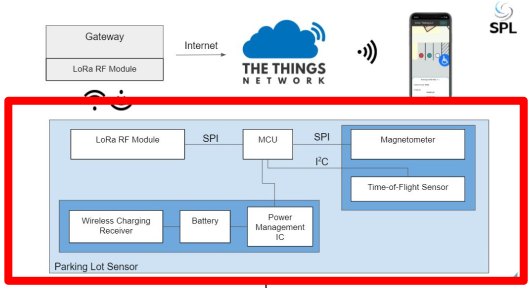
- PCB layout
- Sensors
- 3D-Printed Case

Function Verification

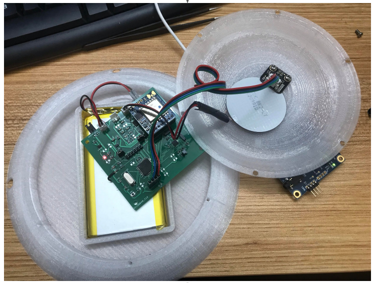
- Time-of-Flight (Lidar) Sensor
- Magnetometer
- Wireless Charging

Challenges

- LoRa Communication



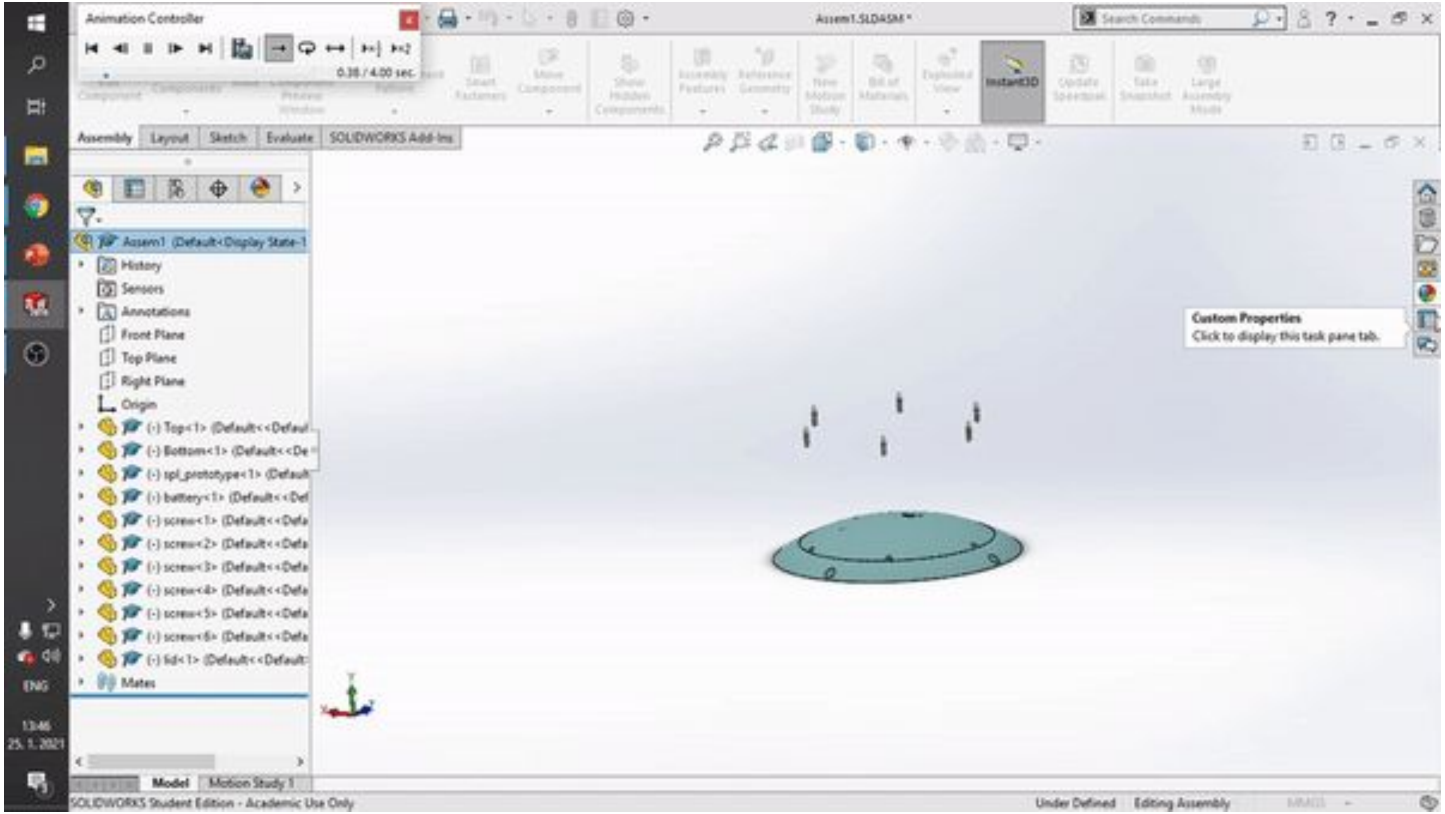
Idea



Hardware Implementation

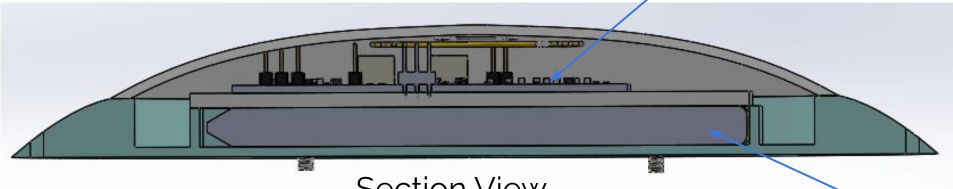
Application Scene Testing

Hardware Explosion View

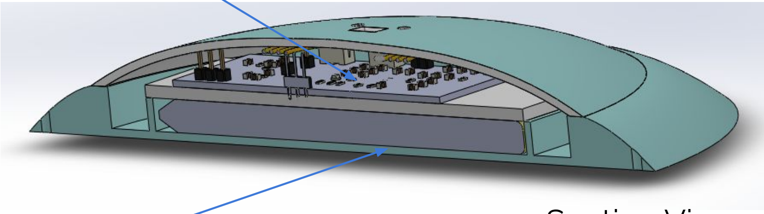


Sensor Unit Assembly

PCB Assembly

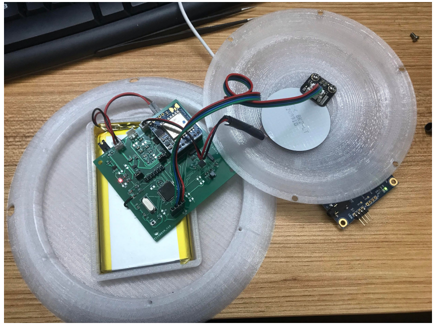


Section View

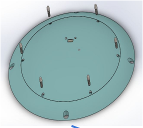


battery

Section View

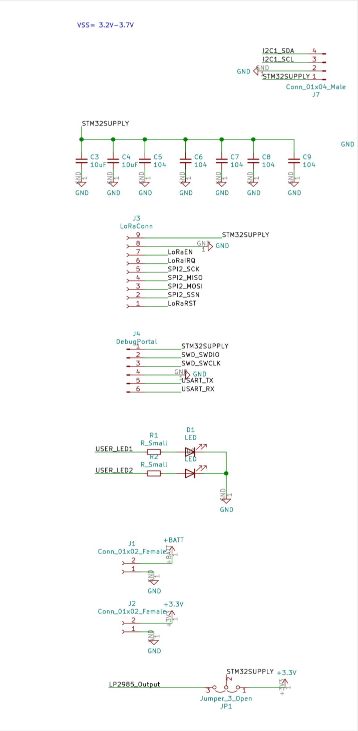


Physical Assembly

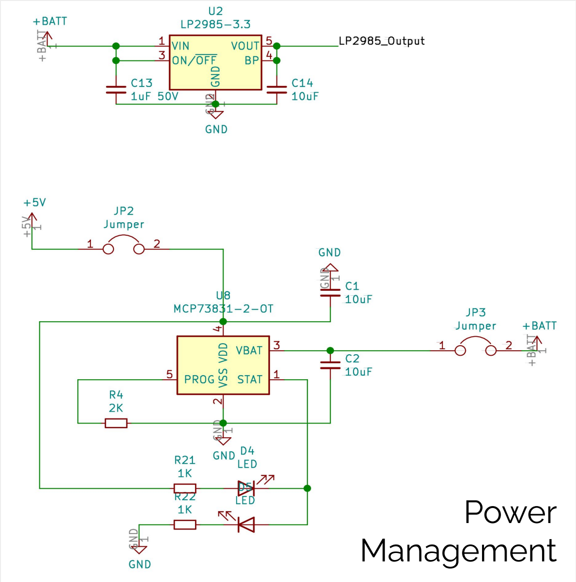


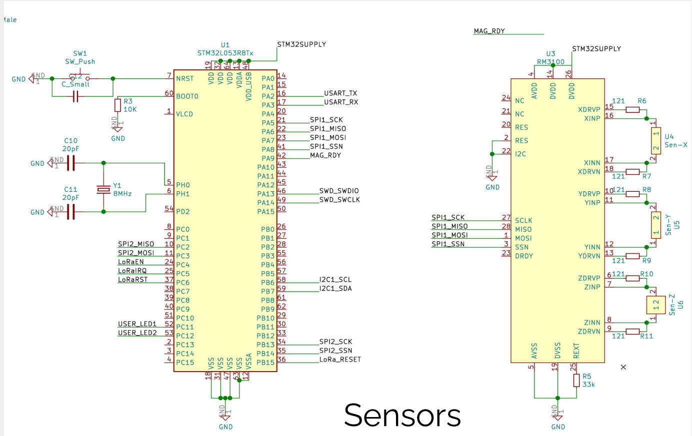
Application Scene

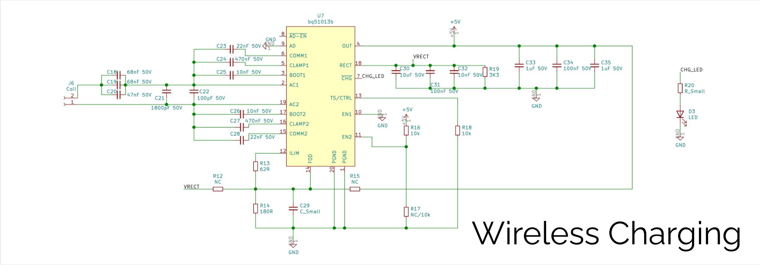
Schematics



Connectors/Filtering







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PCB Assembly

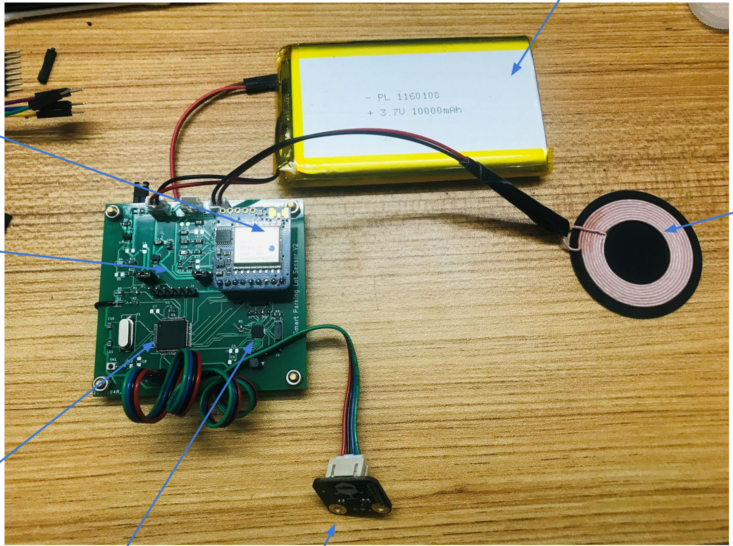
- Designed with Kicad
- 60mm x 60 mm
- Estimated Power Consumption: 22 mA peak
- Will be Refined to 4-layer

battery

LoRa

Power Management

Charging Coil

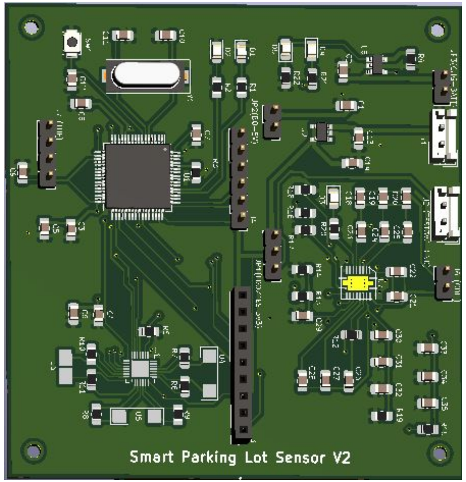


MCU

Magnetometer

Time-of-Flight sensor

Assembled Top View



Kicad - 3D View

Wireless Charging

Charging

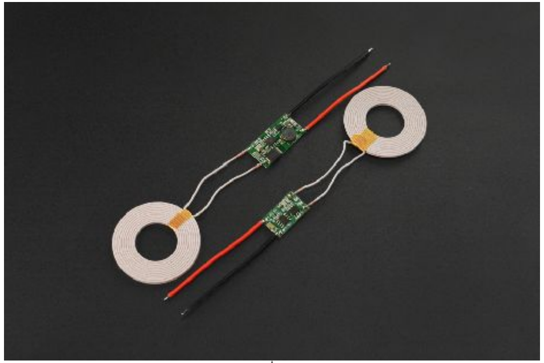
- Domed shaped unit attached to top of sensor unit

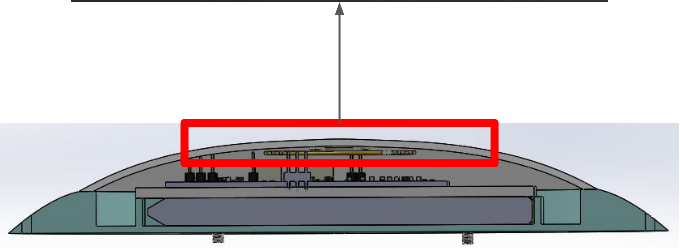
Estimates

- 5 years ~= 45000 hours
- Peak Power Consumption - 22 mA
- Charging - 4 hour

Advantages

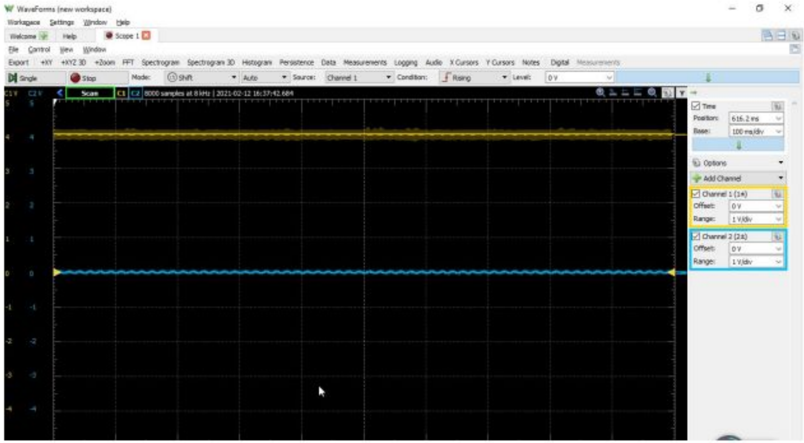
- Sensors still operable when charging
- Maintenance WPC v1.2





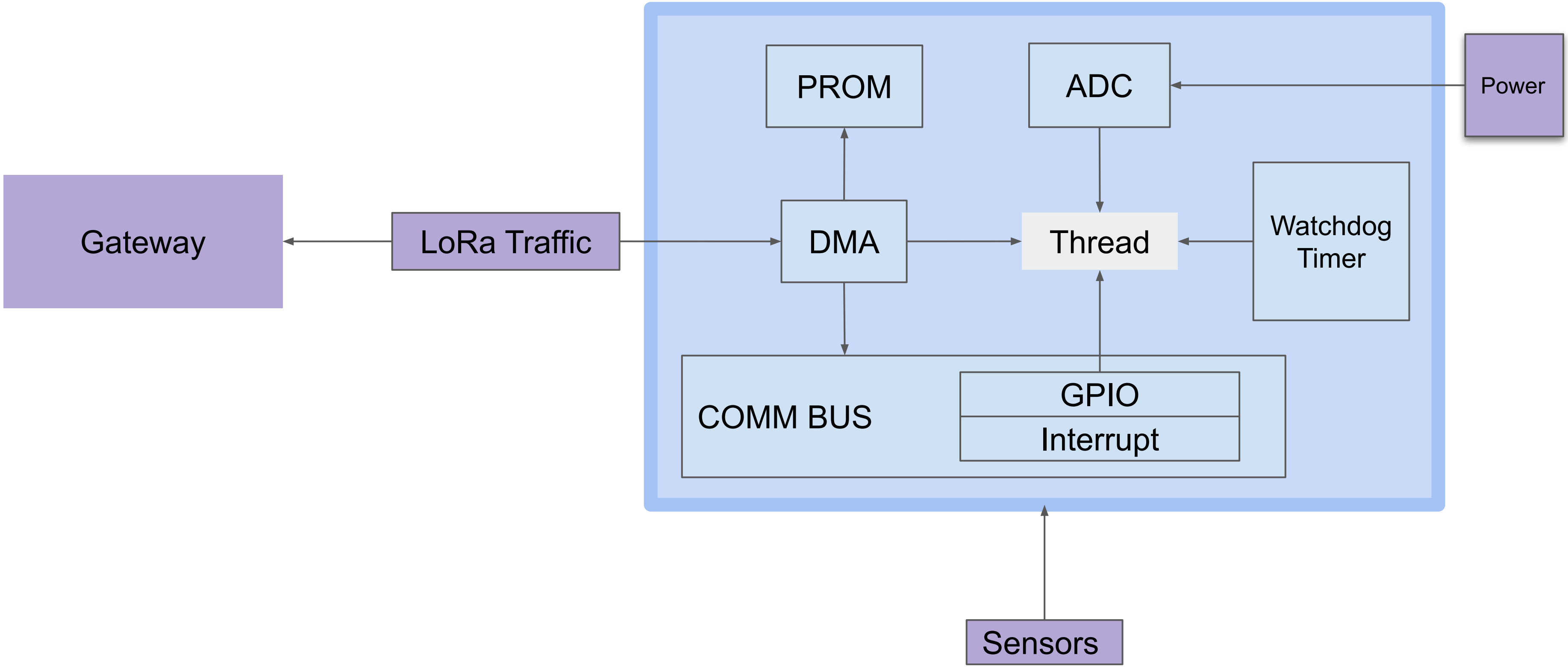
Section View Charging Coil

Wireless Charging Demo



Charging Voltage: 4.2V

Firmware Design Block Diagram



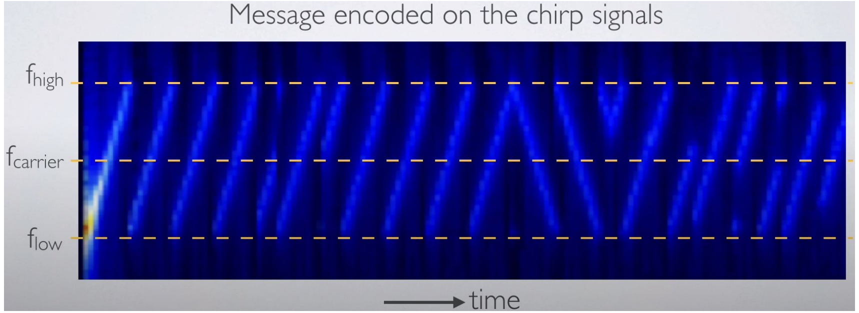
LoRa/LoRaWAN

Long Range Wide Area Network

- Long range (2 km up to several hundred km)
- Trades off having low bandwidth for long range and low power consumption
- Chirp Spread Spectrum Modulation
  - Similar to Frequency Shift Keying

LoRa vs. LoRaWAN

- LoRa = physical layer
- LoRaWAN = network stack
- LoRa can be used on its own as a communication protocol



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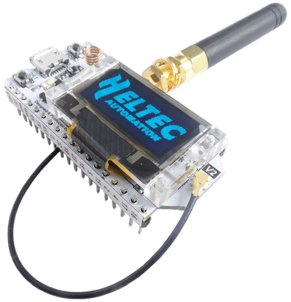
LoRaWAN Testing

STM32 I-NUCLEO-LRWAN1

- 860 MHz to 1020 MHz frequency range
- 14 dBm to 20 dBm transmission power
- -137 dBm receiver sensitivity
- 2.0V to 3.6V voltage range

Heltec ESP32 LoRa 32 (V2)

- 868 MHz to 915 MHz frequency range
- 15.5 dBm to 19.5 dBm transmission power
- -139 dBm receiver sensitivity
- 3.3V to 7V voltage range



Dev Boards for Testing

LoRaWAN Testing

Range Testing

- Tested connectivity across two interconnected parking structures
- Lost connection at about 250m (~820 ft) lateral distance through 5 floors

Multiple device Testing

- Simultaneous message sending through same channel
- Different channel receiver bandwidth testing

Effective Range

Gateway

The Things Industries TTIG-915 LoRaWAN Gateway

- 8-channel Omnidirectional Gateway
- +27 dBm transmit power
- Supports US 915 MHz Frequency Band
- Internet Connectivity using WiFi
- Officially Supported by *The Things Network*

Tested with LoRa development modules and *Raspberry Pi*

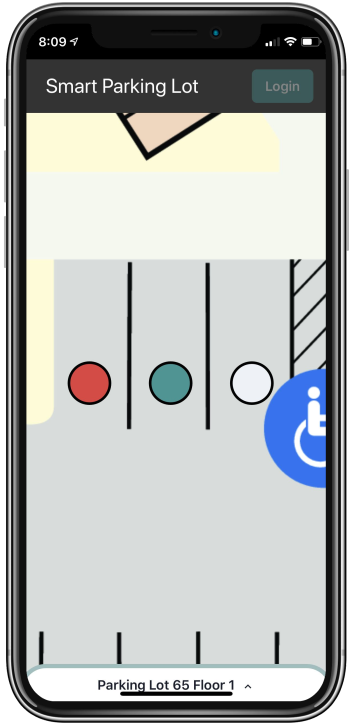
The Things Network

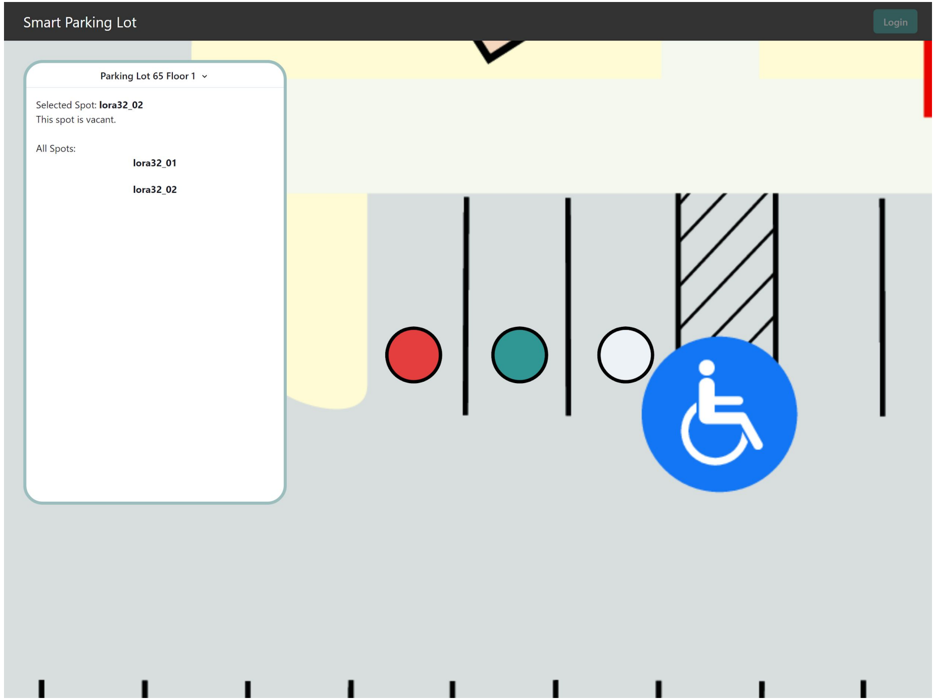
- A free and open-source service for hosting LoRaWAN devices and gateways
- Scalable, secure, used by over 136,000 developers
- Provides API endpoints for retrieving device data packets using JSON
- Historical data from *The Things Network* will also be cached in a MongoDb database

UI / Software Frameworks

- Starting with mobile-optimized web application, which will then be ported over to a native mobile application
- Frontend built using React and Chakra UI
- Backend built using Next JS
- Initial prototype implementing API routes to *The Things Network* completed and functional for current LoRa nodes

Progress - Software





Schedule: Spring Quarter

Winter Quarter, Week 10 to Spring Quarter, Week 1

- **Debug LoRaWan Firmware**
- **Finish Web App, start testing**
- **Field Test with the Assembled Unit**
- **Start on final version of PCB**

Spring Quarter, Week 2-4

- **Finish Testing for Web Application**
- **Transfer Web App into Android / iOS Application**

Spring Quarter, Week 5-7

- **Final Testing for Complete Solution**

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Thank you!

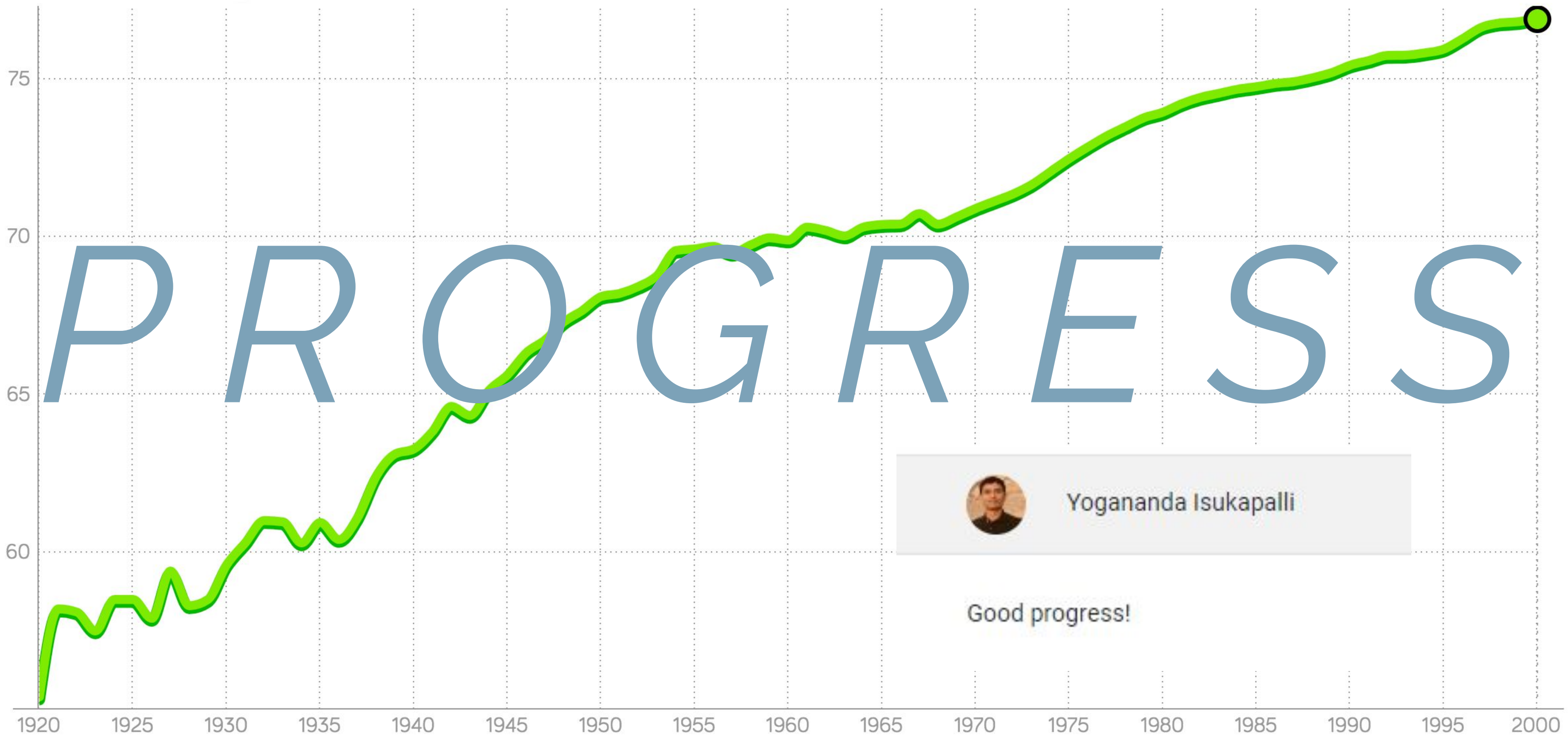
Questions?

Acknowledgements

Professor **Yogananda Isukapalli**
Teaching Assistants **Boning Dong, Trenton Rochelle**

Qualcomm

PROGRESS



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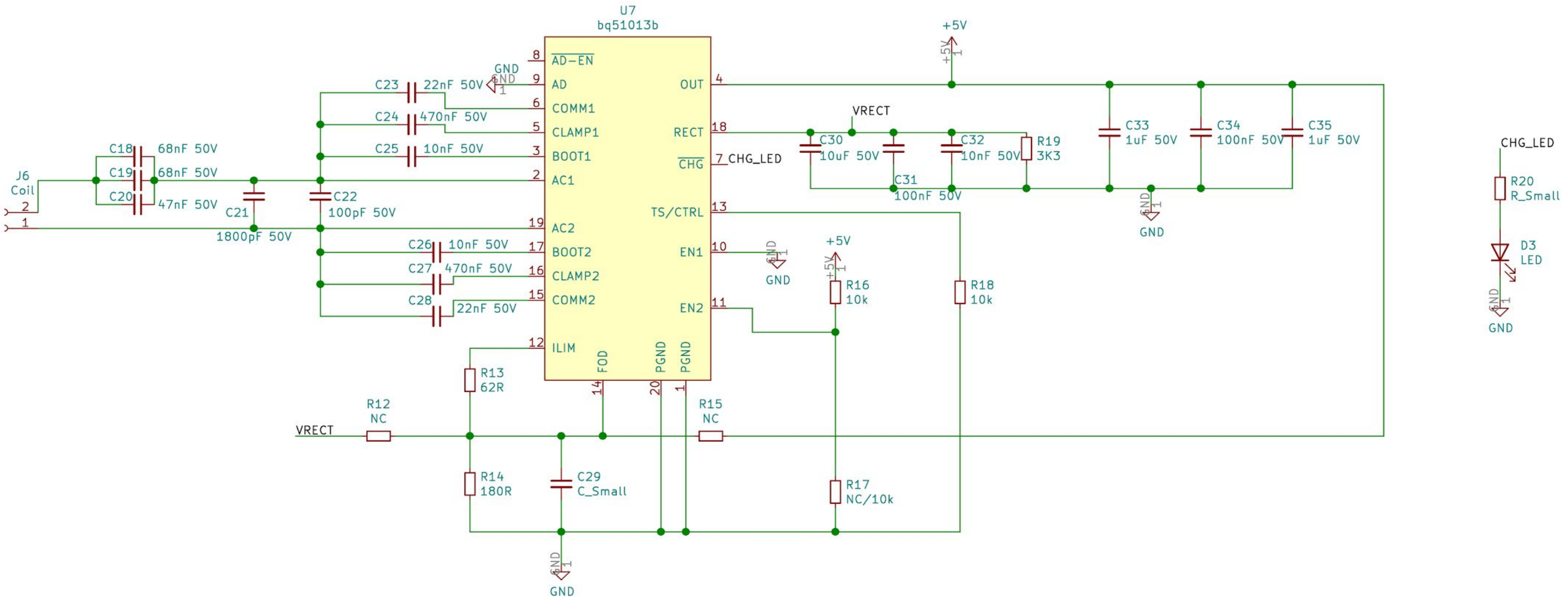
2000
Yogananda Isukapalli
Good progress!

Wireless Charging Schematic



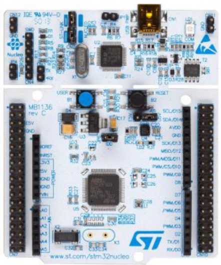
STM32L053r8

Power consumption
- low power consumption
- 88 µA/MHz in Run mode
- 0.27 µA Standby mode

Peripherals
- SPI/I2C/USART
- EEPROM for storing device ID

Firmware Development
- Nucleo

Packaging
- QFP64



ST Ultra-low power product line

STM32L5	• 32-bit Arm® Cortex®-M33 + FPU at 110 MHz • From 256 to 512 Kbytes of Flash memory • Lowest power mode + RAM + RTC: 0.35 µA
STM32L4+	• 32-bit Arm® Cortex®-M4 + FPU at 120 MHz • From 512 Kbytes up to 2 Mbytes of Flash memory • Lowest power mode + RAM + RTC: 0.39µA
STM32L4	• 32-bit Arm® Cortex®-M4 + FPU at 80 MHz • From 64 Kbytes to 1 Mbyte of Flash memory • Lowest power mode + RAM + RTC: 0.34 µA
STM32L1	• 32-bit Arm® Cortex®-M3 at 32 MHz • From 32 to 512 Kbytes of Flash memory • Lowest power mode + RAM + RTC: 1.2 µA
STM32L0	• 32-bit Arm® Cortex®-M0+ at 32 MHz • From 8 to 192 Kbytes of Flash memory • Lowest power mode + RAM + RTC: 0.67 µA
STM8L	• 8-bit STM8 core at 16 MHz • From 2 to 64 Kbytes of Flash memory • Lowest Halt mode: 0.3 µA

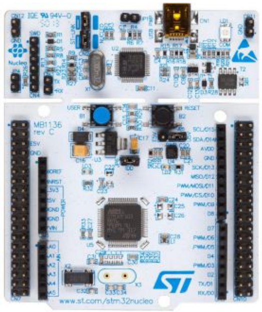
Vehicle Detection Sensors

- Main Factors to consider
  - Power Consumption
  - Installation
  - Lifespan of component
- Sensing Technologies
  - Magnetometer
    - Magnetoresistive (inductive)
    - Hall Effect
    - Differential Hall Effect
  - Ultrasonic
  - Infrared
  - Light Grid

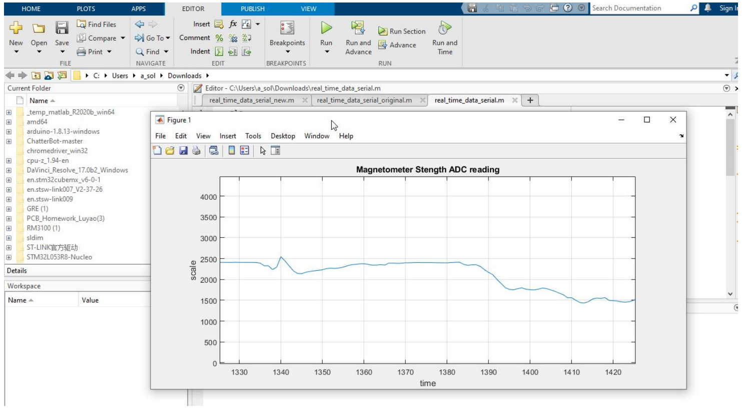
Vehicle Detection Sensors - Experiment Setup

Sensor	Mechanism	Result
LM351LT	Hall Effect	Failure
TLE4921	Differential Hall Effect	Failure
RM3100	Magneto-Inductive	Success
HC-SR06	Ultrasonic Sensor	Success

SPI/I2C/ADC



UART



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Smart Parking Lot

Communication Modules					
Mechanism	Name	Type	Application Notes	Active Transmitting Power Consumption	Pricing?
LoRaWAN	SX1272	LoRa Shield	SPI interface		$25 (Digikey)
	SX1261/1262	LoRa Shield	SPI interface		$30 (Digikey)
	I-NUCLEO-LRWAN1	STM32 Expansion board	USART interface Also uses the SX1272 chip		$28.90 (Digikey)
	STM32WLE5 Series	SoC with LoRa Connectivity	Still relatively new (released this month) Dev boards for this may not exist	15 mA at 10 dBm, 87 mA at 20 dBm	$6 per chip (but just the chip)
	B-L072Z-LRWAN1	Dev board for Lora	Uses SX1276		$46.50
ZigBee	P-NUCLEO-WB55	Dev board for Zigbee / BLE		75mA maximum MCU	$43.75 (Digikey)
	STM32WB Series	SoC with Zigbee and BLE			
	Silicon Labs EFR32MG13	SoC with Zigbee and BLE	Used in IKEA's TRADFRI lineup of smart home products	8.5 mA at 0 dBm, 35.3 mA at 14 dBm	

	Name	Type	Sensitivity/Range	Application Notes	Will it Work?
Magnetoresistive	HMC1051/1052/1053	Part	Typical 1mV/gauss ±6 Gauss	Very complicated. Comes as an primitive analog package, need complicated op-amp circuits to harness the reading, then use ADC reading;	Used successfully to detect vehicle in USC research paper, page 53 It will work with constant ADC reading
	RM3100 Module (Amazon)	Module	Typical 15 nT ±800uT	SPI interface	Given vehicle magnetic field strength typically in uT range, it should response to vehicle passing
Ground Loop	N/A	N/A	N/A	Too expensive for installation/operation	
Hall Effect Switch	SM351LT	Part	±1.1mT Trip, ±0.2mT Release	Simple connection	Not likely, given the price we will try it
Differential Hall Effect Switch	TLE4921	Part	Adjustable through a back magnet, up to ±80 mT	Simple connection	Depends on bias of the back magnet

talking about technology used...