# Smart Parking Lot

Fall Quarter Review

# *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?**

# *Solution*

- A **small, inexpensive wireless device** that will be placed on a parking spot
- Device can last **five years on a single charge**
- Device contains a **vehicle-detecting sensor** that can detect whether a car is parked in that particular spot
- Devices connected with **low-power communication protocol** to a central gateway device. Gateway device propagates sensor data to the Internet, which allows users to view parking spot availability through a **mobile application or website**.

# *Roles*

Short-term Responsibilities:

- Finn L. and Luyao H. - Vehicle detection sensor research
- Andrew L. and Jun C. - Communication module research

Long-term Responsibilities:

- Andrew L. - Parking Lot Terminal / Gateway
- Finn L. - Wireless Communication/ Power Management
- Luyao H. - Sensor Firmware / PCB Design/ Wireless Charging
- Jun C. - GUI / Path Finding Algorithm

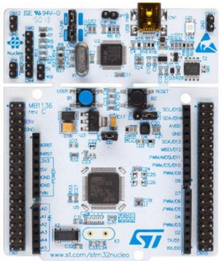
## STM32L053r8

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

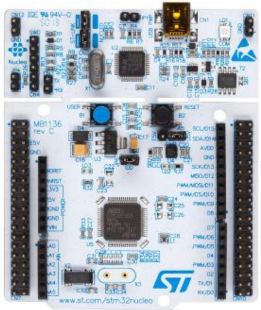
# Vehicle Detection Sensors - A Closer Look

| | Max Sensing Range | Size of Target | Power consumption (average current) | Environment Noise | Lifespan |
|---|---|---|---|---|---|
| **Wireless Magnetometer** | Depends on the size of target | All sizes | < 1 mA | Ambient Magnetic Field | < 20 years |
| **Wireless Ultrasonic Sensor** | 4 meters | All sizes | > 5 mA | Dust, Tangible Particles | < 20 years |
| **Radar Sensor** | <50 meters | Large, predictable targets (e.g. trains) | > 50 mA | Relatively stable | < 6 years |
| **Optical Sensor (Infrared)** | <100 meters | 5 millimeters or greater | > 20 mA | Sensitive to ambient light, sunlight | 2~8 years |
| **Measuring Light Grid** | <2 meters | All sizes | > 200 mA | Sensitive to ambient light, sunlight | unknown |

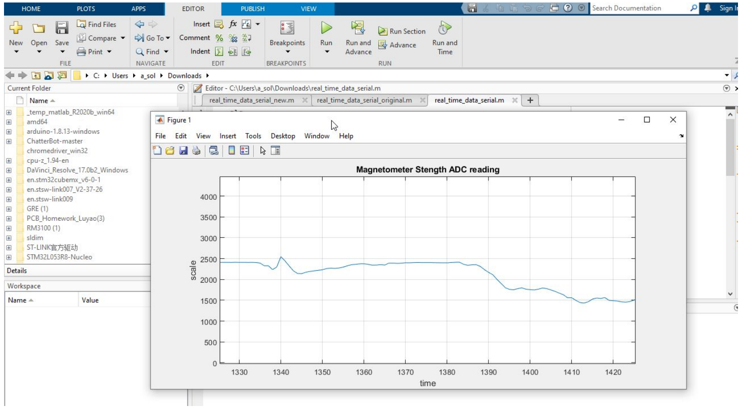
# Vehicle Detection Sensors - Experiment Setup

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

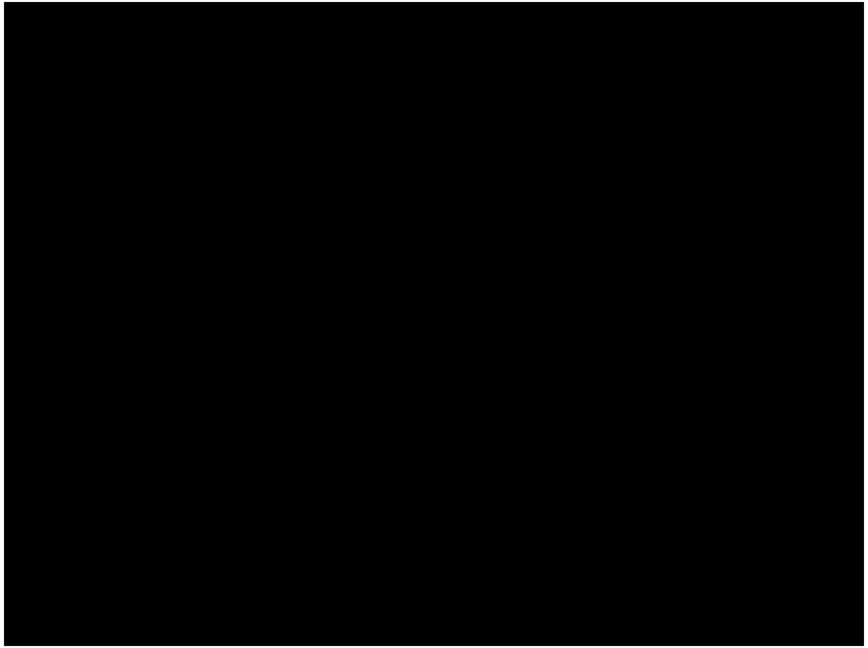
SPI/I2C/ADC

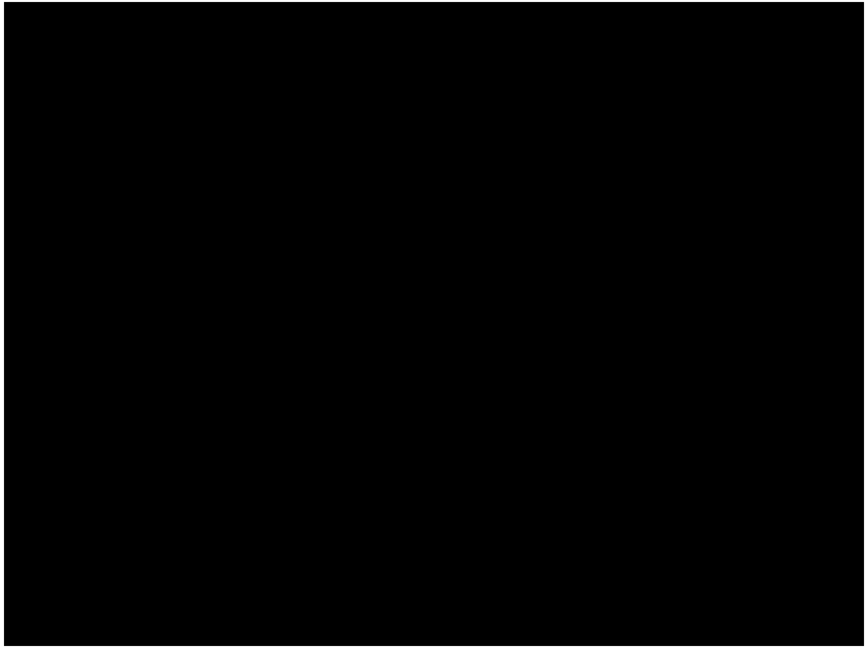


UART



# Vehicle Detection Sensors - Experiment in Parking Lot 22





*Wireless charging*

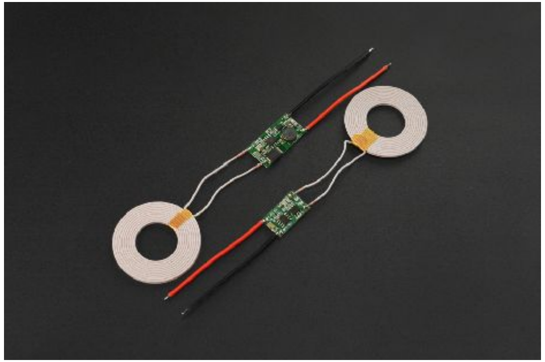
Deployable Wireless Charger

Charging
- Domed shaped unit attached to top of sensor unit

Estimation
- 5 years ~= 45000 hours
- calculated power consumption 0.22 mA
- Charging 2.5 hour with 15W charger

Advantage
- Sensor still operable when charging
- Convenience for maintenance

Disadvantage
- Distortion to sensitivity of magnetic sensor
- Could be stolen



# *Communication*

- Low Power Consumption
- Must support high number of concurrent devices
- Range from sensor to gateway
- Data rate negligible
- Robustness to interference
- Availability & cost

# Communication Protocols / Modules

| | Max Transmitting Range | Frequency (Potential Interference) | Data Transmission Rate | Power Consumption | Part(s) Used for Testing |
|---|---|---|---|---|---|
| **Zigbee** | 10-100 meters | 2.4 GHz | 250kbps | 2.96 J | STM32WB55 Nucleo Pack |
| **LoRaWAN** | 2-15 kilometers | 433 MHz,<br>868 MHz,<br>915 MHz | 0.3-50 kbps | 3.50 J | STM32 I-NUCLEO-LRWAN1 Expansion Board<br>Heltec ESP32 LoRa 32 (V2) Development Board |
| **WiFi** | 50 meters | 2.4 GHz,<br>5 GHz | 150-200 Mbps | 5.00 J | N/A |
| **Bluetooth Low Energy (BLE)** | 50-150 meters | 2.4 GHz | 1 Mbps | 4.5 J | N/A |

Due to concurrent device limitations, power consumption concerns, and transmission range, we are starting with the Zigbee and LoRaWAN communication standards.

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# *Zigbee*

## STM32WB55 Nucleo Pack

- Nucleo68 uses STM32WB55RG
- USB Dongle uses STM32WB55CG
- Both support IEEE 802.15.4 / Zigbee 3.0

## STM32WB55 Series MCUs

- Based on Arm Cortex M4
- Up to +6 dBm transmission power
- -100 dBm receiver sensitivity
- 1.7V to 3.6V input voltage range
- 600 nA in standby, 5.2 mA when transmitting

# LoRa/LoRaWAN

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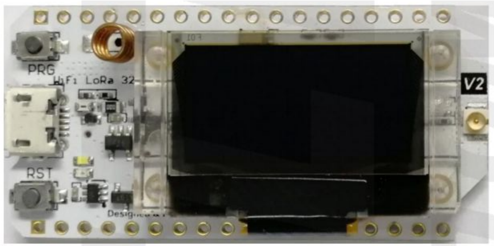
## STM32 I-NUCLEO-LRWAN1

- Semtech SX1272
- 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)

- Semtech SX1276
- 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



# Battery

- Battery needs a minimum of 5 year life
- Current power consumption ~150mA
- Maximum batter with suitable dimensions is 10Ah
- Must cut power consumption by a degree of 100
- Transmitter is the most costly hardware
- Sensor / processor power consumption are minimal (micro amps)
- Transmit every 30 seconds

# *Power Management IC (PMIC)*

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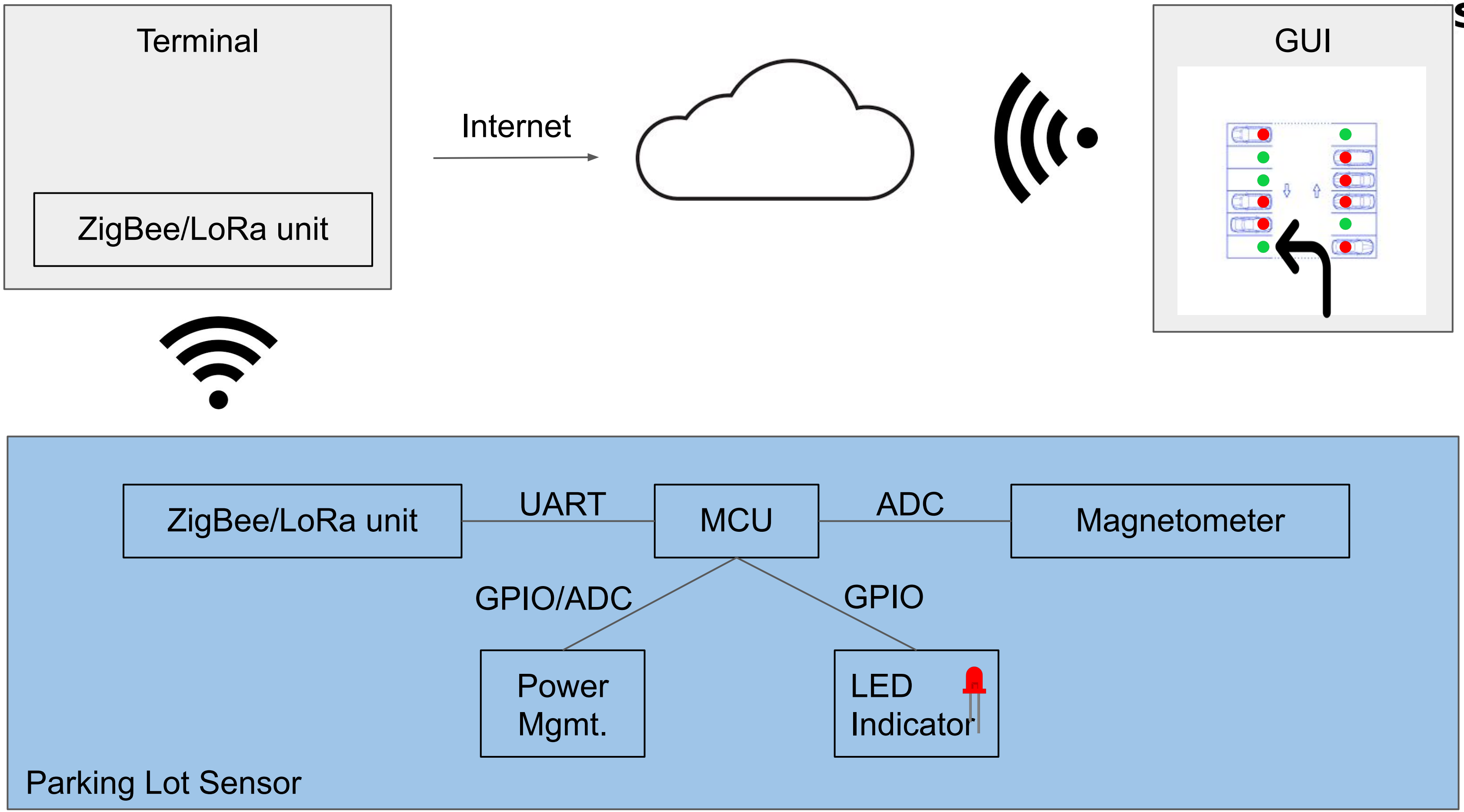
LP3905

- -.2V to 6V range
- 0 to 600 mA range
- Used typically for low power handheld devices
- 2 Buck Regulator (DC2DC step down voltage/Step up current)
- 2 LDO (Low Dropout  Regulator)
- No Recharge
- Need a second PMIC specifically for charging


Terminal
ZigBee/LoRa unit
Internet
GUI
ZigBee/LoRa unit
UART
MCU
ADC
Magnetometer
GPIO/ADC
GPIO
Power
Mgmt.
LED
Indicator
Parking Lot Sensor

# Schedule: Fall Quarter

Fall Quarter, Week 8

**Finalize Initial Parts Testing**

Fall Quarter, Week 9-10

**Prototyping PCB for individual sensor units**

- **power management**
- **wireless communication units**
- **various sensor and test ports**
- **wireless charging receiver**
- **communication bus ports**

**Updating and development of firmware**

Winter Break

**Receiving manufactured PCB for assembly**

# Schedule: Winter Quarter

Winter Quarter, Week 1~2

**Developing gateway data collection software**

**Revision of sensor unit PCB, part selection**

Winter Quarter Week 2-5

**Prototyping wireless charging transmitter**

**Developing Android app prototype**

- **displaying parking vacancy**
- **pathfinding algorithm**

Winter Quarter Week 6-9

**Deploying large amount of sensor units to Parking Lot 10 for field test**

# Schedule: Spring Quarter

Spring Quarter, Week 1~2

**Mechanical case design**

Spring Quarter, Week 3

***Final Product***

Spring Quarter, Week 3-8

**Power consumption optimization**

**Firmware design optimization**

**Battery charging efficiency optimization**

**Android App User Experience Survey**

**Market Value Survey**

Spring Quarter, Week 9

**Documentation**

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# *Thank you!*

## Questions?

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