CS 481

Project Portfolio

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# Abstract

Too much time and effort are spent by those looking for a place to park in one or more garages in downtown Coeur d’ Alene. Commuters would benefit greatly from a system that indicates whether there are spaces available for parking within a parking garage. The Parking Sensor (placeholder name) will allow people to find open parking spaces, and hopefully provide this information before they enter the garage. The means of indication will be via LEDs; a green light means there is an open stall, where a red means the stall is currently occupied by another  
vehicle. This is not the complete functionality of the system, but rather a level of abstraction for the consumer; the data that is measured/collected, will be distributed from device to device via a mesh network, then sent through a gateway where it will be received at The Den as a means of data collection for possible further research. A companion app may or may not be added if necessary.

Specifications:• 5 prototypes will need to be made; 3 for inside the garage, 1 for the entrance and 1 for the exit. The rest of the project will be simulated.  
• Units will be roughly no larger than 4” X 4” X 4” but may be smaller if possible.  
• Each unit needs to be able to last for at least 1 year via battery power.  
• The medium used for vehicle detection can be any type of sensor, or other device capable of detection, so long as it meets the rest of the project requirements.  
• The medium used for communication between devices/server, can be any type, so long as it is wireless, and meets the rest of the project requirements.  
• The units need to be affixed to the garage via some means of adhesion that is non-permanent.  
• Each unit should have a way of being reset, for maintenance, error occurrence, etc.  
• Units will need to have the ability of a deep sleep mode, waking via hardware interrupt, or set intervals.

Software and Networking:• Data sent/received by each unit should, at the very least, maintain integrity and authentication; confidentiality of data is not needed.  
• Units will need to rotate the position of “gateway”, to maintain reliability, and an equal distribution of power consumption throughout the system.  
• Units will interact with each other via a mesh network.  
The validity of the project will be simulated using the data collected from the 5 prototypes within a replicated environment, to show an accurate representation of what the final scope of this project would look like, i.e. if a unit was placed in every stall of the parking garage.

# Problem Definition

Park-IT-CdA is a parking garage monitoring system located in Coeur d’Alene, Idaho at the parking garage between 3rd and 4th Avenue and along Coeur d’Alene Avenue. It is capable of detecting when a car is parked in a stall and will relay this information to a server which will monitor the parking garage’s statistics such as: time from entering the garage to finding a stall, average time a stall is occupied, average number of stalls used.

The objective of this document is to state the requirements of the Garage Sensor System (GSS). The GSS is comprised of 5 Garage Sensor Units (GSU). The GSUs will decide among themselves which is to be the Garage Sensor Master (GSM).

## Functional Requirements

**User Interface Requirements**

There are 3 categories of users of the GSS.

* Drivers – people who use the garage and park inside it. Drivers interact with the GSS when they park their car in a stall that is monitored by a GSU.
* Maintenance staff – a person who must monitor the physical condition of each GSU and clean them, change batteries as required.
* Owner – the person who owns the garage must be able to see the real time statistics of the garage.

What it should do

* The GSS is comprised of 5 GSUs.
* The GSS must periodically check and accurately detect whether a car is parked in a stall
* A Garage Sensor Unit (GSU) is assigned to a parking stall and must indicate externally with LEDs whether a stall is occupied or available
* The LEDs of the GSU must always be solid, or blink at a rate to not cause seizures. All LEDS must blink at the same time
* The GSU must use sensor(s) to determine whether a car is parked in a stall
* One GSU must be placed at the entry of the parking garage
* One GSU must be placed at the exit of the parking garage
* The GSUs must be arranged in a mesh network
* The GSUs must determine amongst themselves which will be the Garage System Master (GSM)
* The GSM must rotate on a periodic basis to conserve battery life
* The GSUs must transmit data periodically about the state of their parking stall to the GSM
* The GSUs must be synchronized to be able to send and receive the data periodically
* The GSU must operate at a speed fast enough to send and receive the data reliably
* The GSM must transmit data periodically about the status of all GSUs to the Garage Sensor Gateway (GSG) at the Innovation Den on top of the roof
* The GSG must relay this information to the server at the Innovation Den downstairs
* The server must process this data and simulate the rest of the parking garage
* The Parking Garage Simulator (PGS) must be located on the server
* The PGS must display statistics of the parking garage such as the number of and location of currently occupied stalls, number and location of available stalls, average time from entry to find a stall.

## Mechanical Requirements

The GSS consists of 5 GSUs located in the garage and a GSG at the Innovation Den.

Strength

The GSU must be capable of supporting its own weight.

Spatial

The enclosure of a GSU must fit within the following:

* Length 4 in
* Width 4 in
* Height 4 in

Or equivalent volume in cubic inches (64 in3)

Weight/Mass

The mass of the GSU must be light enough that it will not fall from its mounting point – see 5.4.

Mounting / Interface

* The GSU must be mounted to a concrete ceiling.
* The method of mounting used must not cause any permanent damage and be removeable leaving no evidence of having been there.
* The GSU must be removeable from the mounting bracket used.

Appearance

* The GSU will have a bubble-dome camera cover over it. The dome is not part of the 4”x4”x4” spatial requirement.
* The GSU must display the UofI colors – gold, silver, black, white
* The following are the primary colors used by UofI and the values used for printers, images, websites, etc.
* Pride Gold
  + Pantone 3514 C
  + CMYK 0-27-100-0
  + RGB 241-179-0
  + #F1B300
* Silver
  + CMYK 0-0-0-50
  + RGB 128-128-128
  + #808080
* White
  + CMYK 0-0-0-0
  + RGB 255-255-255
  + #FFFFFF
* Black
  + CMYK 20-20-20-100
  + RGB 25-25-25
  + #191919
* Metallic Gold
  + PMS Metallic 871

Durability

The GSU must be constructed to handle the environment that it will be located – (see section 8). A GSU must be able to last 5 years.

Reliability

Each GSU must be able to operate for 1 year continuously on one battery charge. Maintenance must be performed at the 1-year mark to clean the surface of the sensors/dome and change batteries.

## Electrical Requirements

Operational Voltage

* The GSU must be capable of running off batteries/battery packs
* During operation the voltage of the GSU must run at 3.3V to power all hardware

Operational Power Capability

During operation, the GSU must be capable of supplying enough power for all electronic components.

Energy Storage Capacity

* The batteries of the GSU must have enough capacity to run for a year
* The hardware and software must minimize power usage
* The GSU must have the ability to go into a sleep mode to conserve battery life
* The total mass of the batteries must not be so high as to compromise the mounting system

## Software Requirements

Functionality

* The software for this project will consist of the control software for the GSU and the simulation
* The GSU software must interface with the sensors to identify when a parking stall is occupied
* The GSU must be in a sleep state to conserve battery when not transmitting or detecting
* The GSU must be activated from its sleep state when a (1) sensor detects a car in its parking stall
* The GSU must use all its sensors to confirm whether the first sensor successfully detected a car or not
* The GSU must have multiple sensor activation positives to confirm that a car is parked or not
* The GSS must be able to have the time synchronized to provide consistent LED blinking
* Each GSU must be able to communicate with every other GSU in a wireless mesh network
* There must be a priority system in place to determine which of the GSUs will be the GSM
* The GSUs must transmit its data to the GSM periodically
* The GSM must periodically transmit all the GSU data wirelessly to the GSG located at the Den
* All communication between the GSUs and the gateway must provide Integrity and Availability of the CIA triad
* The GSG at the Den will have the ability to be able to remotely reset all the GSUs.
* The simulation software must use the data received from the GSG to perform a simulation of the entire garage
* The simulation must graphically display the current state of each parking stall, the average time from when a car enters the parking garage to when it parks, the number of occupied stalls and number of available stalls

User Interface

* If time permits, an IOS or Android app will be created to provide a visual user interface for drivers of the car park
* The app must contain the same information as the PGS
* The GSU will be able to be provisioned when installing in a parking stall

## 

## Environmental Requirements

Temperature

The GSS must have full operational capabilities in a sheltered outdoor environment and run under industrial temperatures (-40 to +85 C).

Environmental Sealing

The unit is not expected to be directly exposed to rain. However, water – brought in from vehicles during wet and snowy weather, dust – from wind, oil from vehicles and smoke from vehicles is expected.

* The GSU must be waterproof and dust tight
* The external sensors of the GSU must be able to perform without maintenance for a year with any debris build up that does occur

## Regulatory Requirements

FCC Requirements

The GSS must comply with all FCC requirements when transmitting wirelessly.

## Cost Requirements

Prototype Cost

The cost to build and install 5 prototype GSUs, including test units, batteries and housings, must not exceed $1500.

## Deliverables

5 GSU’s including all hardware

Software to run them – Arduino sketches, simulation

User manual

# Project Learning

## Mesh Network

Date: 9/19/19

Team Member: Nikolai

Subject: LoRa Mesh Network

Category: Software Research

Outcome: Found a site that has a basic implementation of a mesh network using LoRa located at <https://nootropicdesign.com/projectlab/2018/10/20/lora-mesh-networking/>

Looks like it could use a useful starting point

Date: 10/21/19 – 10/22/19

Team Member: Nikolai

Subject: LoRa Testing

Category: Hardware and Software Testing

Outcome: Had soldered the LoRa boards the previous day and was now testing the boards using the RadioHead library and three Arduinos.

I first use the mesh network that I found last month.

First attempt results in an “init failed” message on the serial console.

I then use the tutorial provided at <https://learn.adafruit.com/adafruit-rfm69hcw-and-rfm96-rfm95-rfm98-lora-packet-padio-breakouts/rfm9x-test>

Double check the solder joints and pins and they look ok. They also have a wiring diagram, so I follow what they have shown.

* Vin -> Vin
* Gnd -> Gnd
* SCLK -> 13 Uno, 52 Mega
* MISO -> 12 Uno, 50 Mega
* MOSI -> 11 Uno, 51 Mega
* CS -> 4
* RST -> 2
* G0 -> 3

Try uploading the client/server sketches to two Arduinos and “init failed” again.

Use a multimeter to measure voltages and make sure power is going to the LoRa boards.

I then go through the sketch and look to see whether there is anything mentioning pins 11, 12, 13, 2, 3, 4 since they correspond to the pins.

I then find #defines for RFM95\_CS, RMF95\_INT and RFM95\_RST are set to 10, 9 and 2. These correspond to CS, G0 and RST respectively however the Pins do not match up with the wiring diagram (maybe older version of hardware was used). I correct this and it works – the console outputs of both Arduinos show that they are communicating.

I attach a multimeter and the power draw is 75mA idle, and 100mA when transmitting which is huge.

I then upload the mesh network sketches to the 2 Arduinos I have, and they all communicate. To get the mesh network going required a program to modify the EEPROM so that there was an ID stored that the mesh network would retrieve for use.

Memory usage: RFM95 Client Server uses 8K FLASH (25%), 893 Bytes of RAM (43%).

Mesh network – 13.7K FLASH (42%), 1447 Bytes of RAM (70%).

I solder the third LoRa module and test that. Decide to go field test this in the garage today.

Date: 10/22/19

Team Member: Nikolai, Tyrel, Zane

Subject: LoRa Range Testing

Category: Hardware and Software Testing

Outcome: After the previous nights’ work of getting the LoRa boards and mesh network working, I (Nikolai) decide we should go to the garage and test the range out.

I have 3 Arduinos each with a LoRa board connected and they are all working as expected, printing the status of the network to console output.

Test conditions:

* 3 Arduino Uno/Mega with a LoRa radio attached – A Garage Sensor Unit (GSU)
* Used the LoRa mesh network implementation at https://github.com/nootropicdesign/lora-mesh
* Broadcasts at maximum power – 100mA per transmission
* This implementation periodically sends messages including the Received Signal Strength Indicator (RSSI) of each radio in the network
* Using a laptop and console, measure how far another GSU can be before connection drops out (Goal is to get to the garage ~400 ft away)

One Arduino is placed by the entrance to the UofI’s office at the Den and connected to mains power. I then have one connected to my laptop with serial console active to see the LoRa messages. The third is connected to a 9V battery. The Relative Signal Strength Indicator (RSSI) is typically around -60 when in the same room.

Once we step outside of the Den, the RSSI has already dropped to -90. Halfway down the car park next to the Den at the RRSI is at -120 and drops out. We head to the parking garage and me and Zane stand by the car entrance/exit and Tyrel takes the battery powered Arduino and starts walking up the ramp to the next floor and then to the third floor. The signal doesn’t drop out until he is at the farthest corner on the second floor but otherwise is around -90 to -120 RSSI.

Tyrel then stands on the second floor with Line of Sight to the Den rooftop and Zane and I walk back to the Den to measure signal strength. We get to where the Gateway would be located on the rooftop next to the Den and get -100 to -110 RSSI even without LOS and even get similar signal strength with the Arduino plugged in downstairs.

This experiment has proved that using LoRa would the project is viable.

Google map view of where the signal dropped out.



Google Map view of how far away the signal reached outside.



## Sensors

Using Sensors – Ultrasonic and PIR, testing with the car in garage – Zane

## Simulation

Simulation Environment and setting it up – Tyrel

## Arduino

Date: 10/15/19

Team Member: Nikolai

Subject: Testing Arduino Pro Minis

Category: Hardware testing

Outcome: Tyrel had given me an Arduino Pro Mini the day before and I tried to upload the blink sketch to it to see if it would work. Had no success in doing this and tried troubleshooting for several hours getting nowhere – was the bootloader an issue, hardware issue, an Arduino IDE setting? Couldn’t work it out and gave up.

Date: 1/1/20

Team Member: Nikolai

Subject: Testing MKR WAN 1310

Category: Hardware and Software Testing

Outcome: Over the break I wanted to test out the MKR WAN 1310 Arduinos we got to confirm that it will work with the Radiohead library and the mesh network implementation we want to use as a starting point.

Upload of the mesh network sketch would fail to init the RFM95 module. Going back to the send and receive test that Adafruit has resulted in the same thing. Spent about 6 hours troubleshooting and found out that the LoRa chip on the board isn’t compatible with the RadioHead library. LoRa and RadioHead are not the same thing either even though it seemed like they were. The result is that this board is not going to be usable without having to completely learn how to do all the sending and receiving from scratch.

Other things learnt from this: the processor on the MKR WAN 1310 is the SAMD21 instead of the ATMega 328P. This has a different instruction set such as for setting timer and sleeping. There are more timers – 5 for the SAMD21 and fewer sleep modes – 3. There is no EEPROM on the SAMD21 either which the mesh network implementation needs – each node needs a unique ID. This will require a different method for obtaining an ID, probably the MAC address or radio ID – take the last 2 or 3 digits. There is also a way to emulate EEPROM on flash, but it gets erased each time a sketch is uploaded. <https://github.com/cmaglie/FlashStorage>

The watchdog timer on the SAMD21 cannot be used too generate an interrupt like that ATMega: it’s purely for system resetting.

Date: 1/1/20

Team Member: Nikolai

Subject: Finding a suitable Arduino unit for the project

Category: Hardware Research

Outcome: Since the MKR WAN1310 is unlikely to be the route I want to go for the base unit, I needed to quickly find some other Arduino/LoRa combo units and just order them myself to find if they will be useful. I want to at least verify that we have something usable before the Spring semester starts in 2 weeks.

Since the first LoRa chips were bought from Adafruit, I start there and find the Adafruit Feather M0 which also uses the SAMD21 processor and has a built in LoRa chip. It doesn’t have the built-in encryption module and they claim 300 uA in sleep mode. I buy 2 of them. This is something we should have done last semester: pick out a wide range of units and buy 1-2 of each to test out.

Date: 1/8/20

Team Member: Nikolai

Subject: Testing Adafruit Feather M0 LoRa

Category: Hardware and Software Testing

Outcome: I want to test out the sending and receiving on the board to see if it will work with the RadioHead library. It works, which is a relief. I then do some testing on sleeping and use a timer to put it to sleep before waking up and blinking the LED. The result of this is 2.78mA during sleep mode. We’ll need to work on improving that number. I think this is the unit we should use.

## Batteries

Battery research – Everyone who looked it up

Stuff we did in CS 443 that’s relevant – everyone who took it

Template

Date:

Team Member:

Subject:

Category:

Outcome:

Date:

Team Member:

Subject:

Category:

Outcome:

# Project Management

## Team Members

Nikolai Tiong

Roles

* Team Leader
* Mesh network design
* Network hardware design
* Hardware Testing
* Documentation

Zane Goodrich

Roles

* Sensors for the GSUs
* External hardware design
* Hardware Testing
* Documentation

Tyrel Parker

Roles

* Simulation Software
* Hardware purchasing
* Documentation

Joel Berain

Joined Spring 2020

Roles

* Organizing the Wiki page
* Getting caught up on the project
* Documentation

## Meeting Minutes

Date: 8/27/19

Start Time: 3:30 pm

End Time: 4:45 pm

Location: Innovation Den

Present: Nikolai, Tyrel, Zane, Dr Sheldon, Dr Shovic

Agenda: Introduction to the class, what it is, what to do. Dr Sheldon is the instructor, while Dr Shovic will be the customer in this iteration of instead of Dr Shovic being both in the previous year.

Everyone talks about themselves and how they got there – an introduction to everyone in the group.

Outcomes: The project is given to us by Dr Shovic. It involves car parks like the Park My Ride project last year but this time it will be to design and build autonomous sensors in the car park that has recently been built. We need to build 3-4-5 prototype sensors in car park stalls of our choosing which must detect when a car is park – motorcycle is optional since it is a lot harder. The units must communicate with one another and then relay their information to a “gateway” in the Den. They need to run on battery for a year. There will also be a simulation that must be created which uses data from the sensors to simulate the rest of the garage. The communications will need to be done over a wireless technology and needs to be encrypted somehow. Must have at least Integrity: it wasn’t tampered with and Authentication: it came from out devices of the CIA triangle.

To Do: None

Date: 8/29/19

Start Time: 3:30 pm

End Time: 4:45 pm

Present: Nikolai, Tyrel, Zane, Dr Sheldon

Location: Innovation Den

Agenda: Dr Sheldon goes over the official overview of the class based on what students do at the Moscow campus.

There is a website <https://www.webpages.uidaho.edu/mindworks/capstone_design.htm> that hosts the document templates and presentations to go over the semester.

Dr Sheldon then introduces a PhD student Muhammed who will be able to aid should we need it.

Everyone exchanges emails so that we can start communicating outside class.

We need to now work on an abstract of the project, a calendar listing milestones, use case diagrams, context diagrams and prepare questions to interview Dr Shovic shortly so that we can get a better idea of what is required for the project. Someone also needs to record meetings.

We need to share our schedules as well to coordinate meetings outside of class.

Outcomes: First assignment has been given out, prepare to interview Dr Shovic

To Do: Abstract – Zane

Use Case Diagram – Tyrel

Calendar – Tyrel

Context Diagram – Zane

Recording Meetings – Nikolai

Interview Questions - Nikolai

Date: 9/5/19

Start Time: 3:30 pm

End Time: 4:40 pm

Present: Nikolai, Tyrel, Zane, Dr Sheldon

Location: Innovation Den

Agenda: We’ve just interviewed Dr Shovic and now Dr Sheldon wants us to explain the project to him.

We need a way to organize our documents so that we can collaborate on them.

Outcomes: Tyrel has created a Github for us to store documentation.

Continue working on the upcoming deliverable, they are due Tuesday 9/10/19.

The main parts of the project are battery life – we need to keep these units running for a year on battery with an LED on and a mesh network that allows each unit to communicate wirelessly.

We should use something like LoRa or Sigfox for wireless communication – distance from the garage to the Den may be an issue with WiFi.

We have a budget of $3,000.

We need to find something with low power usage.

To Do: Project Overview Document – Zane

Use Case – Zane

Context Diagram – Tyrel

Schedule of Deliverables for the project – Tyrel

Tidy up interview questions and post to Github – Nikolai

Record meeting notes and post to Github - Nikolai

Date: 9/10/19

Start Time: 1:45 pm

End Time: 2:20 pm

Present: Nikolai, Tyrel, Zane

Location: Innovation Den

Agenda: We decide to meet prior to class today to go over the diagrams that need to be turned in. Tyrel thinks his use case diagram is too simple.

Outcomes: The use case diagram is simple, but it looks like it covers everything at the level of abstraction we need. The rest of the documents look ok too.

Other things discussed:

Do the parking sensors need to be numbered 1, 2, 3, 4, 5 etc. so that the simulation knows where it is in the garage.

Types of sensors to use: IR, sound, light, motion.

How long should a sensor be active for to confirm it is occupied. What base unit to use: Arduino Nano? Zane has taken Embedded Systems (CS443), while Tyrel and I are taking it right now, so we are going to get some practice using it.

To Do: None

Date: 9/10/19

Start Time: 3:30 pm

End Time: 4:45 pm

Present: Nikolai, Tyrel, Zane, Dr Sheldon

Location: Innovation Den

Agenda: Follow on from meeting just before, we turn in the documents.

Dr Sheldon is giving a presentation about sustainability and being green.

Outcomes: Dr Sheldon wants us to start using logbooks to record thoughts and processes.

The first major milestone is the Preliminary Design Review which is due a month from now.

To Do: We need to work out who is going to do what major part of the project. We’ve identified three different areas: sensing cars, mesh network and simulation.

Date: 9/12/19

Start Time: 3:30 pm

End Time: 4:45 pm

Present: Nikolai, Tyrel, Amanda

Location: Innovation Den

Agenda: Zane can’t come in today and Dr Sheldon is sick. However, he and Dr Shovic arranged to have Amanda, who was in the capstone last year to come in and talk to us instead.

Decide who is going to do what on the project.

Outcomes: Amanda talked about the logbook and how she focused on it more early on and gradually used it less as the project went on.

Zane was already leaning towards doing the hardware and sensing so he will do that, Nikolai will do the mesh network and Tyrel will do the simulation.

To Do: Create a discord server to communicate easier - Tyrel

Date: 9/17/19

Start Time: 3:30 pm

End Time: 4:45 pm

Present: Nikolai, Tyrel, Zane, Dr Sheldon

Location: Innovation Den

Agenda: Tyrel has created the Discord server.

We have a new document to work on – the product requirements specification based on the interview with Dr Shovic.

The template provided on mindworks raises a lot more questions that requires a follow up meeting with Dr Shovic, such as physical appearance and environmental factors.

Dr Sheldon wants to us to identify the 3-5 main driving requirements of the system and what is its purpose.

We need to write up a team contract – how the team will work on the project and rules, roles and responsibilities of each member.

The mid-semester snapshot is the week beginning 10/21/19 where we are expected to have done the following:

* Finished product requirements spec
* Preliminary Design Spec
* Possible Prototype
* Experiments to try with the prototype once hardware comes in

Outcomes: Nikolai has been designated as the customer liaison.

New acronyms have been created: GSS – Garage Sensor System, GSU – Garage Sensor Unit, GSG – Garage Sensor Gateway

Questions for next meeting with Dr Shovic:

* What the data collection is for – from the units
* What is included in the data – stall number, time vacant, occupied
* What is the purpose of the simulation, what does it mean by simulation, what exactly are we simulating, what it will look like
* How long to find a stall based on different occupancy levels
* Can a sensor unit detect more than one stall – reduce number of units to purchase

Need to clarify language used in documentation such as will, should, must.

To Do: Schedule another meeting with Dr Shovic this week to go over project requirements spec – Nikolai

Come up with a team name – everyone

Keep up with Logbook entries

Date: 9/19/19

Start Time: 3:30 pm

End Time: 4:45 pm

Present: Nikolai, Tyrel, Zane, Dr Sheldon

Location: Innovation Den

Agenda: Have just had second meeting with Dr Shovic.

Team names, Nikolai provided a list of possible names.

We need to come up with ways to verify that the requirements of the product are met once we have documented them as well as come up with testable requirements.

Outcomes: Park-It-CdA is the team name.

Dr Shovic needs to obtain permission from the city to allow us to do stuff in the garage like install the GSUs.

Looking at using Arduino Uno or Nano for base unit and LoRa module for wireless communication using the Radiohead library at Dr Shovic’s suggestion.

Need to work out how to configure the GSUs when deploying them.

The Simulation should use an existing package like Simulib and graphical output.

The mesh network should have a designated master unit (Garage Sensor Master - GSM) that will send data to the GSG located at the Den

To Do: Tidy up interview notes and post to GitHub – Nikolai

Continue work on product requirements specification – Nikolai

Continue work on schedule + Gantt chart – Tyrel

Research Arduinos and LoRa modules to purchase – Everyone

Research batteries - Everyone

Draft budget - Tyrel

Date: 9/24/19

Start Time: 3:30 pm

End Time: 4:45 pm

Present: Nikolai, Tyrel, Zane, Dr Sheldon

Location: Innovation Den

Agenda: LoRa chips, Arduinos, ordering hardware.

Outcomes: We should get about 3-5 units of whatever we purchase to test out.

We should also investigate all-in-one boards that contain everything we need.

To Do: Research hardware further to try and order for Thursday – everyone

Continue work on product requirements specification – Nikolai

Continue work on schedule + Gantt chart – Tyrel

Date: 9/26/19

Start Time: 2:00 pm

End Time: 3:00 pm

Present: Nikolai, Tyrel, Zane

Location: Discord

Agenda: Zane was sick, and Tyrel was busy at work, so we didn’t have an in-class meeting but instead talked on Discord.

Nikolai has filled out most of the Product Requirements Spec, the main part remaining is electrical research and batteries.

Outcomes: We don’t have a lot of room for batteries – 4” x 4” x 4”.

Weight of the GSU with batteries will be an issue.

Arduino Unos use a lot of power even in sleep – 15.5mA according to documentation so that is out – a 2500 mAh battery would be drained in a week at that rate.

Regular batteries like AA or D batteries are probably not going to work – 6 V 10,000 mAh in AA’s requires 16 of them.

Zane found in his research the Arduino Pro Mini which uses only 4.2 uA in sleep.

A good LoRa module looks to be the Adafruit RFM95W and use 0.2uA in sleep mode.

To Do: Keep researching hardware and batteries – everyone

Continue work on product requirements specification – Nikolai

Continue work on schedule + Gantt chart – Tyrel

Date: 9/29/19

Start Time: 12:00 pm

End Time: 2:00 pm

Present: Nikolai, Tyrel, Zane

Location: Discord

Agenda: Tyrel wants to know if we have anything to propose for buying.

The draft product requirement spec, budget and schedule are due Tuesday but nowhere on blackboard to submit it.

Discussion on batteries and power usage again.

3D printing a case for the GSU

Outcomes: Nikolai has suggested the Sparkfun Arduino Pro Mini 328 - $9.95, and Adafruit LoRa RFM95M for $17.96 (10+). Should buy 20 or each so that we have 5 in garage and 5 each for testing. Total cost would be about $500 – 20% of budget. Also need to get antennas and uFL to SMT connectors for it.

Zane has created a 3D model of the unit.

We will need to use LiPo battery packs but finding an appropriate one >10000 mAh that doesn’t look like a cheap one is difficult to find.

We must consider self-discharge on the batteries since they need to last for a year.

To Do: Inform Dr Sheldon about blackboard.

Tyrel will arrange to purchase the hardware with Carrie at the Den

Continue work on product requirements specification – Nikolai

Continue work on schedule + Gantt chart – Tyrel

Date: 10/1/19

Start Time: 3:30 pm

End Time: 4:45 pm

Present: Nikolai, Tyrel, Zane, Dr Sheldon

Location: Innovation Den

Agenda: Nikolai finishes draft product requirements spec.

Discussion of the mounting system and what to use.

Zane found an ultrasonic sensor he would like to try.

Inform Dr Sheldon of the blackboard situation.

We need to also be working on a project plan document.

Outcomes: Dr Sheldon will add turn in areas on blackboard.

We don’t need to meet on Thursdays anymore if we agree not to beforehand.

Schedule a meeting with Dr Shovic to present the draft spec – 10/3/19 1:30 pm

To Do: Project Plan – Zane

Submit docs to blackboard.

Date: 10/2/19

Start Time: 11:20 pm

End Time: 11:30 am

Present: Nikolai, Tyrel

Location: Harbor Center 240B

Agenda: Informal conversation with Tyrel between CS443 and CS385.

Tyrel ordered the Arduinos and LoRa modules with Carrie and turns out we only have a $1,500 budget instead now.

Inform Tyrel that the submission spot was made available and he can submit the schedule and budget.

Outcomes: Lower budget requires a reworking of the budget

To Do: Adjust budget – Tyrel

Start working on PDR V1 - Everyone

Date: 10/3/19

Start Time: 3:15 pm

End Time: 4:30 pm

Present: Nikolai, Tyrel, Zane

Location: Parking Garage

Agenda: We go on a field trip to the garage to see what we are dealing with.

Outcomes: It’s a lot colder inside the garage than outside strangely – this was during an unusual cold snap though for the time of year.

The ceiling is not even at all places in the garage.

There are horizontal concrete beams that extend approx. 2ft below the ceiling which will block sight of LEDs for cars that are looking for them.

To Do: Continue working on PDR V1 - Everyone

Date: 10/10/19

Start Time: 12:00 pm

End Time: 2:00 pm

Present: Nikolai, Tyrel, Zane

Location: Parking Garage

Agenda: Another garage field trip.

Outcomes: Measured the typical width and length of a stall – 8’5” wide, 17’ long

Counted the number of stalls under cover – 261.

Mapped out the layout of the garage.

Measured the height of the ceiling at several points – ranges from 8’4” to 10’.

There’s some sunlight coming in on the southern side – solar power may be an option to supplement the battery.

The closest point from the garage to the Den on level 2 and 3 have direct line of sight with the rooftop of the Den.

To Do: Continue working on PDR V1 and turn in – Everyone

Start work on PDR V2 - Everyone

Date: 10/17/19

Start Time: 3:30 pm

End Time: 4:45 pm

Present: Nikolai, Tyrel, Zane, Dr Sheldon

Location: Innovation Den

Agenda: Tyrel gives Nikolai the 3 LoRa chips, antennas and connectors.

Review the PDRV2

Outcomes: Got some hardware to test.

To Do: Solder the LoRa chips and test them out – Nikolai

PDR V2 - Everyone

Date: 10/22/19

Start Time: 1:30 pm

End Time: 3:00 pm

Present: Nikolai, Tyrel, Zane

Location: Parking Garage

Agenda: Nikolai has soldered the LoRa chips and tested them out with Arduinos and are ready to be field tested.

Parking Garage field trip to test.

Outcomes: Covered in more detail under Project Learning.

Communication between an Arduino in the garage and in front of the Den is possible even without line of sight.

Communication between Arduinos on different levels in the garage and spots is possible.

Test is successful.

To Do: Document these findings and add to PDR V2 – Nikolai

PDRV2 and Gantt Chart - Tyrel

Date: 10/29/19

Start Time: 3:30 pm

End Time: 4:45 pm

Present: Nikolai, Tyrel, Zane

Location: Innovation Den

Agenda: Discuss the snapshot week presentation, it’s going to be later than expected because of scheduling conflicts with Dr Sheldon and Dr Shovic being out of town at different times.

More battery discussion.

Sensor discussion.

Outcomes: Halloween is Thursday, so we won’t meet then.

Will do the formal presentation on Tuesday 11/5/19.

We should add solar to the hardware design.

Zane wants to use a PIR and ultrasonic sensor for detecting cars, need something capable of detecting 6-8 ft.

To Do: Email Dr Shovic to schedule meeting - Nikolai

Date: 11/12/19

Start Time: 3:30 pm

End Time: 4:45 pm

Present: Nikolai, Tyrel, Zane, Dr Sheldon

Location: Innovation Den

Agenda: We need to do another presentation for the CDR

Outcomes: Dr Sheldon is away next week and then it’s Thanksgiving the week after so there isn’t much opportunity to arrange a time to have everyone meet.

We need to work on a project portfolio containing everything done so far into one document.

To Do: Start working on portfolio – Zane

Date: 11/17/19

Start Time: 9:00 am

End Time: 10:00 am

Present: Nikolai, Tyrel, Zane

Location: Discord

Agenda: Discuss the CDR

Battery usage

Outcomes: We need to update the CDR with milestones

Break down each of our sections into smaller tasks representing significant progress

To Do: Do battery calculations – Nikolai

Order MKR WAN 1310s – Tyrel

Come up with milestones - Everyone

Date: 12/5/19

Start Time: 3:30 pm

End Time: 2:00 pm

Present: Nikolai, Tyrel, Zane

Location: Innovation Den

Agenda: Go over remaining documents to turn in

Outcomes: Peer Evaluations and Logbook Evaluations

Status report update

Project portfolio needs to be created that contains everything done up to this point

To Do: The above documents – Everyone, turn in during finals week.

Date: 12/20/19

Start Time: 12:30 pm

End Time: 2:00 pm

Present: Nikolai, Tyrel, Zane, Dr Sheldon

Location: Innovation Den

Agenda: Turn in portfolio

Turn in evaluations logbook

Discuss what to do for next semester

Outcomes: We’re done for the semester

To Do: Start experimenting with the MKR WAN 1310s - Nikolai

## Client Communications

Date: 9/5/19

Start Time: 2:30 pm

End Time: 3:20 pm

Present: Nikolai, Tyrel, Zane, Dr Shovic

Location: Innovation Den

Agenda: We’ve prepared interview questions. Have printed out copies of the questions.

Interview Dr Shovic to get a better understanding of the project requirements

Outcome: We were intending to ask the questions and record answers, but Dr Shovic decided to just take the sheet and give an entire overview of the project. Then read through the questions and answered them.

The following are the questions and answers given:

Overall Project

- Could you give us an overview of the entire project?

We need to create 5 prototype units attached to ceiling inside the garage that need to be able to sense when a car has parked and when a car has left the stall

3 level garage – not going to touch the roof

Put a unit on garage entrance to check when car enters the garage and one at exit for leaving, the remaining 3 are for stalls of our choice

Display for whether the garage is full.

Discrete event simulator – simulate the rest of the garage, create graphical simulation, real time or not? Up to us to decide.

Don’t know about monitoring cars moving through the garage, probably not

Generate the rest of the sensors in the simulation ~100 or so

Unit properties

1 year on battery – need to measure currents, Dr Shovic has some tools for this and will provide them

Maybe multiple types of sensor on the same unit – IR, photocell, sonar, motion

Must detect a car, other vehicles such as motorcycles are optional

LED connected that blinks – Red – no car, Green – car, idea is that it can be seen by cars looking to park

Mesh Network – transmits to WLAN gateway located at the Den – Sigfox, LoRa – 2.1 GHz, 833 MHz, 433 MHz

Processors – use what we like

Temperature sensor would be cool – not essential

Networking - major part – each sensor can act as the gateway for battery load balancing and in case the master one goes down – need to work it out

4”x4”x4” size approx.

Attachable to ceiling – cement or something

Arduino may be enough for this

Wonderware?

QT?

Able to reset everything

Goal – minimize people’s time and effort to find parking spot

App – optional if can be done do it

Gateway – realistic behavior – car enters, time to go to first level, second level

Tracking entrance and exit

- Title/name? Up to us

- Patent searches. Has this been done? How did they do it? It has, do some research

- Timeline for class? When are our deliverables? The entire system and hardware working for 5 units. We need to come up with milestones, design review. Get through spec phase fast so we can work on hardware and coding faster to sort out issues when implementing.

- How often do we get to meet with our customer? – didn’t answer, will be up to us to decide

- End users - who is expected to use the system? People wanting to park in the garage

- How do they interact with the system? The app

- Do we have a budget for this project? ~$3000 – sensors, gateway, server

- Which parking garage is this project being done on? How large - number of stalls and levels, is it? Believe it is the new one on 3rd street it is 3 level, we must work out the number of stalls by actually visiting the site.

- Have the stalls been selected already, or will we get to visit the garage and pick? We can pick what we want

- Will there be some advertising or advisory saying that monitoring will be going on once the sensors are installed? Research if legal

Hardware

- What base model should we use? esp8266? Something with good power down modes

- What mesh network requires less power? Bluetooth? Don’t know, we have to find out

- Does the entire garage need to be on a single brain?

- Does the brain need to be in the garage? No, it will be in the Innovation Den, do we need a bidirectional data link however? – battery level, synchronized clock, when to have them listen for transmission

- Deep sleep? Heck yes

- Need to save any data from previous time of wakefulness? Maybe/maybe not – eeprom

- How often does each unit need to report? How long does it take on average for a vehicle to enter and exit a stall? Get data. – Go on field trip and find out

- How large are the units expected to be - Will they need to be inconspicuous? 4”x4”x4”

- How do we physically secure these units? Adhesive, tape, maybe put a black dome to look like a camera

- Cost per base? Cost per satellite unit? How do we get component purchases approved? Didn’t answer this, we have a $3000 budget to work with though.

- How do we sense the vehicles? Motorcycles and cars and trucks? Accuracy? What is the definition of stall being full? Lasers cost too much power? – we must work it out ourselves

Software

- Does the data being sent from the sensors need encryption? Confidentiality, Integrity, Authentication – PKI to prevent people forging the data, hashes, CRC

Broadcasting for the sensors – how to determine which sensor gets to broadcast – wait for acknowledgement to be broadcasted? Random fallback time for collisions, number seeding, assigning a serial number to base seeding off, secret – private key, system clock, uptime

Must have Integrity and Authentication at the least

-App – IOS/Android, what is its purpose? Either, allow people to see current state of parking garage

- Will hardware, software and licensing be provided to produce the apps – IOS – need apple computer hardware for Xcode, apple store dev license, iphone/ipad to test the software.

We’ll get it all free – software, hardware didn’t mention, probably not due to the cost of istuff and our budget

- the simulation – is this going to be computationally expensive? Would want to use a PC for it

-Are there any regulations that would limit our implementation? Tools, language, hardware, software regulations that exist? Dr Shovic will obtain permission from the city. Do our own research for the rest

Date: 9/19/19

Start Time: 2:30 pm

End Time: 3:30 pm

Present: Nikolai, Tyrel, Zane, Dr Shovic

Location: Innovation Den

Agenda: Interview #2 with Dr Shovic

Interview questions and answers:

Language in specification document – must, will, should how do we use these words in it?

Must/should are requirements that have to be in the project

Will suggests something that is optional

Permission for project and to visit the garage and not be asked to leave by security.

John is working on this.

Physical Unit (Mechanical Requirements)

Are there any requirements for the physical appearance of the unit?

Black box, metal/plastic/wood housing, with LEDs and sensors sticking out. Or just have the electronics on a board and then house it in a faux camera cover provided it won’t interfere with sensors and LEDs?

We can make use of 3D printers to create what we want.

Gateway – what exactly is this and what does it need to do?

The gateway is the master sensor unit. Transfers data to the server. (I was interpreting this differently, as a router/home gateway located on the Den roof or something – Nikolai)

Environment

Water vapor, smoke, dust, oil is going to potentially get into the unit and interfere with the exposed sensors. E.g. a splatter of oil ends up on a photoresistor, or the LED indicator. Are we expected to have the unit function for a full year with no maintenance on top of running on battery?

Water vapor and dust could also get inside the unit. Goes back to the physical requirements – aim to build a dust-tight, water resistant housing? The faux camera cover everything and protect it from stuff up coming from below.

Operating temperature – aim for the extremes - -20 F to 120+ F (-30 C– 50 C).

Waterproof at least

Make assumptions about the unit getting dirty, e.g. it will run maintenance free for one year and will be cleaned when the battery is replaced

3D printed box could work for this

Industrial temperatures (-40 to +85 C)

Simulation

Will each unit need to be able to know where it is relative to the garage. If we install one on the ground floor in the first parking spot, should we have an identifier for level 1, park 01?

Discrete event simulator – use a package that exists, simulib, event queues, Display, web-based display for remote access, possibly to an app.

The implementation of how to provision the units is entirely up to us. Some ideas include having each unit with a unique ID, which the simulation is then configured to know that GSU1 is located on third floor, stall 5 for example.

Production requirements – do we need to worry about this – estimate annual production and cost per year?

Ignore this part for now

Other things that came up in the interview

Mesh networking – try radio head, probably most complex part of this.

Reporting frequency – as often as necessary once per second to 1 hour as appropriate to function correctly.

Sensor interrupts the system to wake up the unit – power saving

Receiver that listens for wake up signal – less power than a transmitter

Wake everything up at the same time?

OTA updates?

Mounted toward the front of the stall so that the LED can be seen.

Get PCB manufactured if needed

Date: 10/3/19

Start Time: 1:30 pm

End Time: 2:30 pm

Present: Nikolai, Tyrel, Zane, Dr Shovic

Location: Innovation Den

Agenda: Inform Dr Shovic of our hardware choices and gives his thoughts on it.

Ask some further questions about the project.

Outcomes: We need to make sure we match voltages – 3.3V or 5V to avoid stepping up/down voltages since it uses power.

There’s 2 choices of speed for the Arduino Pro Mini 8/16 MHz – 8 MHz may not be fast enough.

Keep in mind the RAM and FLASH available – 2KB/32KB.

We should aim for industrial temperature operation - -40 C to +85 C.

Use PWM for blinking LEDs.

The GSUs will need to be synchronized somehow – DS3231 clock module maybe.

Might need bidirectional communication with the garage and Den.

To Do: None

Date: 11/5/19

Start Time: 1:30 pm

End Time: 2:40 pm

Present: Nikolai, Zane, Dr Shovic, Dr Sheldon, Tyrel (at end)

Location: Innovation Den

Agenda: Preliminary Design Review/Snapshot Day/formal presentation day

Go through the presentation.

Outcomes: Tyrel unable to make it in time due to work.

Dr Shovic liked that the LoRa worked .

We need to define some milestones.

To Do: Start work on Critical Design Review (CDR) - Everyone

Date: 11/21/19

Start Time: 1:30 pm

End Time: 1:40 pm

Present: Nikolai, Zane, Dr Shovic, Tyrel

Location: Innovation Den

Agenda: See Dr Shovic to discuss updates to CDR

Outcomes: He wants us to send a memo on it

To Do: Organize a memo and email him.

## Schedule

## Budget

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Item** | **Quantity** | **Price** | **Total** | **Notes** |
| Adafruit Feather M0 LoRa | 5 | $34.95 | $174.75 | The Arduino we will be using |
| 6V 1W Solar Panel | 5 | $19.95 | $99.75 | For Charging the Battery |
| Solar Charger | 5 | $17.50 | $87.50 | For Charging the Battery |
| 3.8 mm/1.3mm to 5.5/2.1 cable | 5 | $1.50 | $7.50 | Connects Solar Panel to Solar Charger |
| DS3231 RTC | 5 | $13.95 | $69.75 | Clock Module to keep Arduinos in Sync |
| 3.6V 20.1Ah Li ION Battery | 5 | $92.15 | $460.75 |  |
| LoRa Gateway | 1 |  |  |  |
|  |  |  | $900.00 |  |

# Design Solution

## System Diagram

## Component Selection

## User Interface

## Description of Key Features

# Implementation

## Bill of Materials

## Manufacturing Plan

3D printer for case

Soldering as required for electronic components

Installation of gateway on roof of Den

## Engineering Drawing Package

# Design Validation

## Experiment Design

### Mesh Network

These are the milestones and things that need to be tested on the Mesh Network to conclude that it is performing as expected.

A GSM can be determined on power on and on a periodic basis thereafter. If the network is already present, a new GSU being added needs to be able to find the GSM and join the network, otherwise it is going to become a GSM for a different network.

GSUs can transmit data to the GSM either directly or via another GSU. GSUs wake up on a timer to transmit, then go back to sleep. The GSUs and GSM need to be in sync with one another to send and receive data. The receiver is only going to be active for a short period since it uses ~20mA while active.

The GSM can transmit data to the GSG at the Den. This needs to be done on a periodic basis to clear the memory of the GSM since we don’t have a lot of memory to work with.

Data transmitted is encrypted – the payload needs to be encrypted since anyone with a LoRa radio would be able to receive the packets and decipher them. Especially since some of the messages will be control signals.

## Data Collection

The GSUs need to be able to store the sensor data and a timestamp. The GSM needs to store its own data and other GSU data until it transmits to the GSG. This data will be transient.

The server in the Den will permanently store all data that comes in.

## Data Analysis

The Simulation needs to take in this data to analyze and so that it can work out average time from car entry to carpark occupancy.

## Client Acceptance

# References

Arduino

Adafruit Feather m0 pin diagram

<https://cdn-learn.adafruit.com/assets/assets/000/046/204/original/Feather_M0_LoRa_v1.2.pdf?1504806734>

Adafruit solar charging

<https://learn.adafruit.com/products/390/guides>

LoRa

Adafruit Testing RFM95

<https://learn.adafruit.com/adafruit-rfm69hcw-and-rfm96-rfm95-rfm98-lora-packet-padio-breakouts/rfm9x-test>

Mesh Networking test

<https://nootropicdesign.com/projectlab/2018/10/20/lora-mesh-networking/>

Other

University of Idaho, Color Identity,

<https://www.uidaho.edu/brand-resource-center/visual-style-guide/color-identity>

## Acronyms and Abbreviations

* Den – Innovation Den, located at 418 E Lakeside Avenue, Coeur d’Alene, ID
* GSG – Garage System Gateway
* GSM – Garage Sensor Master
* GSS – Garage Sensor System
* GSU – Garage Sensor Unit
* PGS – Parking Garage Simulator