Beacon Indoor Navigation System

Group 14
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Motivation

- GPS technologies are not effective indoors
- Improve on current implementations of indoor positioning
- Help visually impaired people

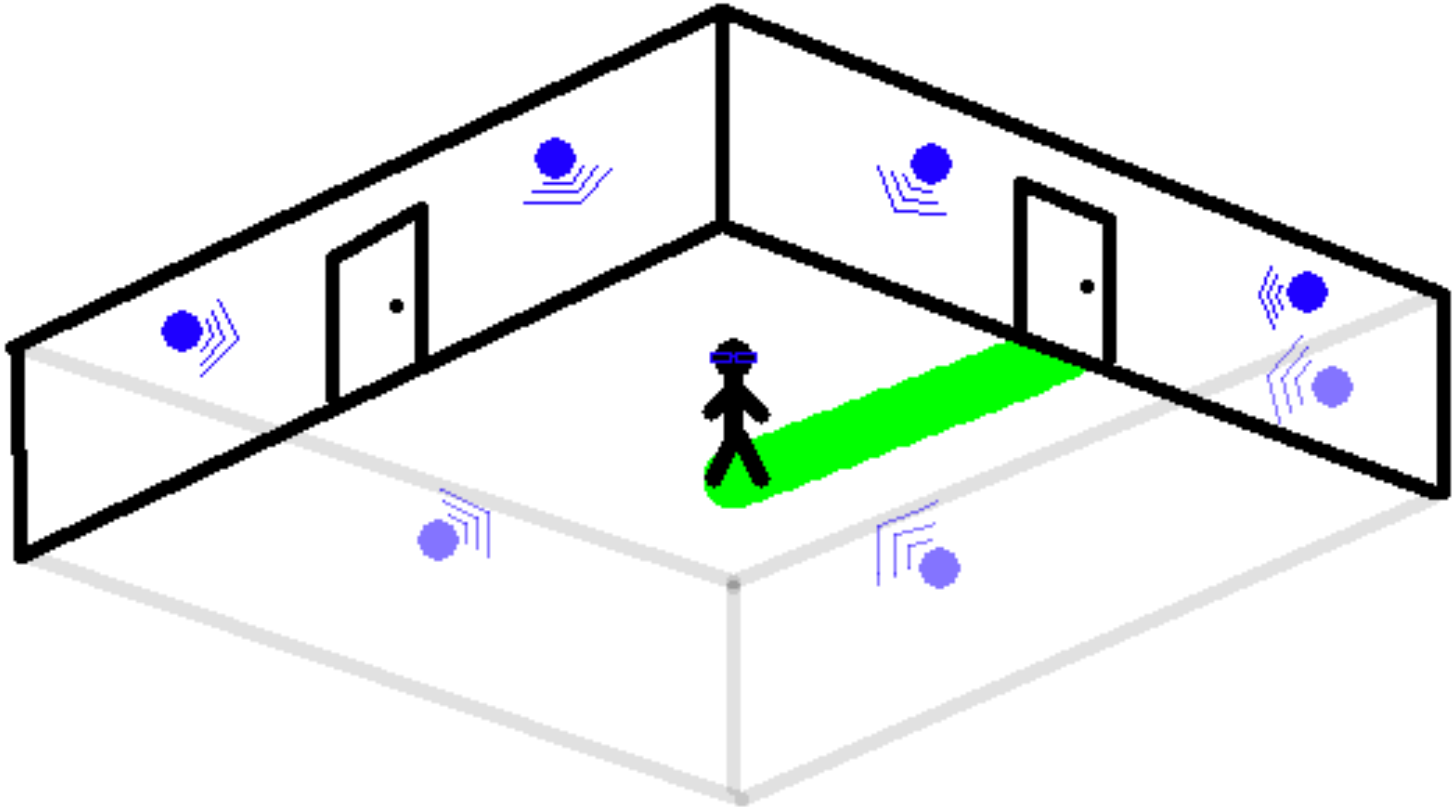
Objectives

- To create an accurate indoor navigation system with an easy-to-use user interface.

- Develop beacons that utilize the Bluetooth Low Energy specification allowing for low power consumption

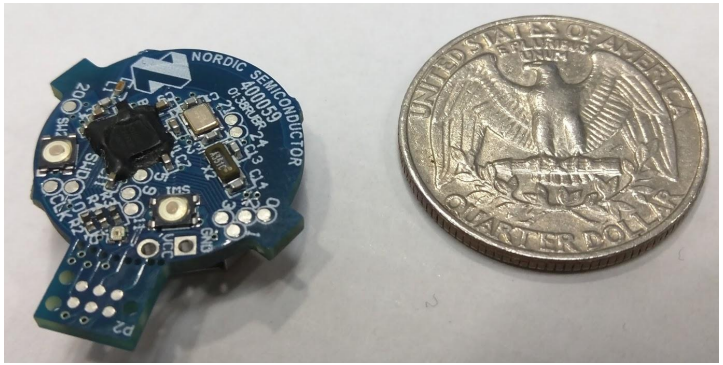
- Provide a complete open-source solution in both hardware and software

System Concept



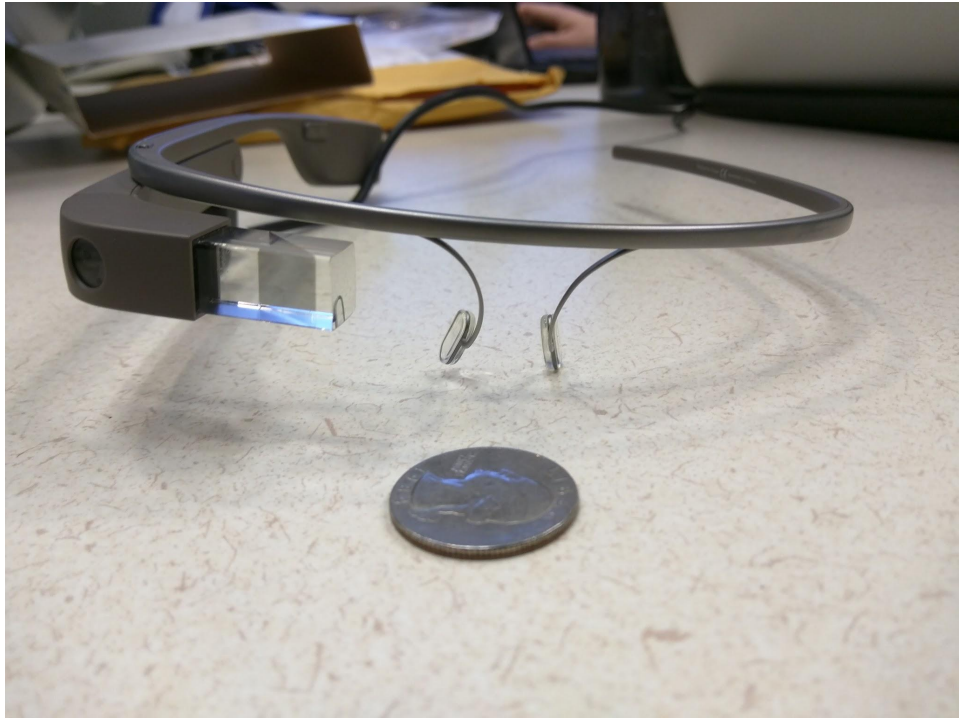
What is an iBeacon?

- Uses Bluetooth 4.0
- Developed by Apple
- Signal contains
  - UUID (Universally unique identifier) - 128-bit value
  - Major - 16-bit unsigned integer
  - Minor - 16-bit unsigned integer
  - Calibration RSSI - 16-bit signed integer
- 100ms advertising interval (Some use 900ms for lower power consumption)

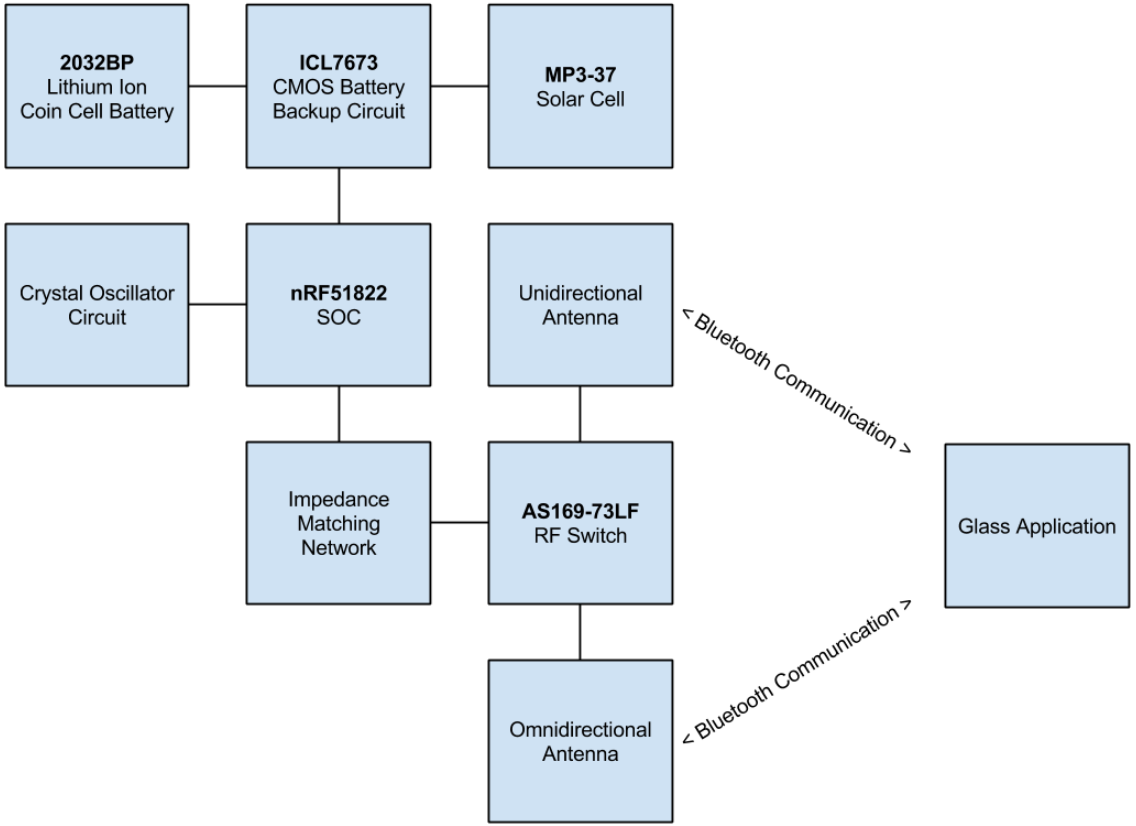


Why Google Glass?

- Allows the user to easily communicate with the device by only using only their voice. (hands-free)
- Allows for easy compatibility with other Android devices.
- Trivial to figure out which way the user is facing
- Investigate the potential advantages of wearables combined with indoor positioning



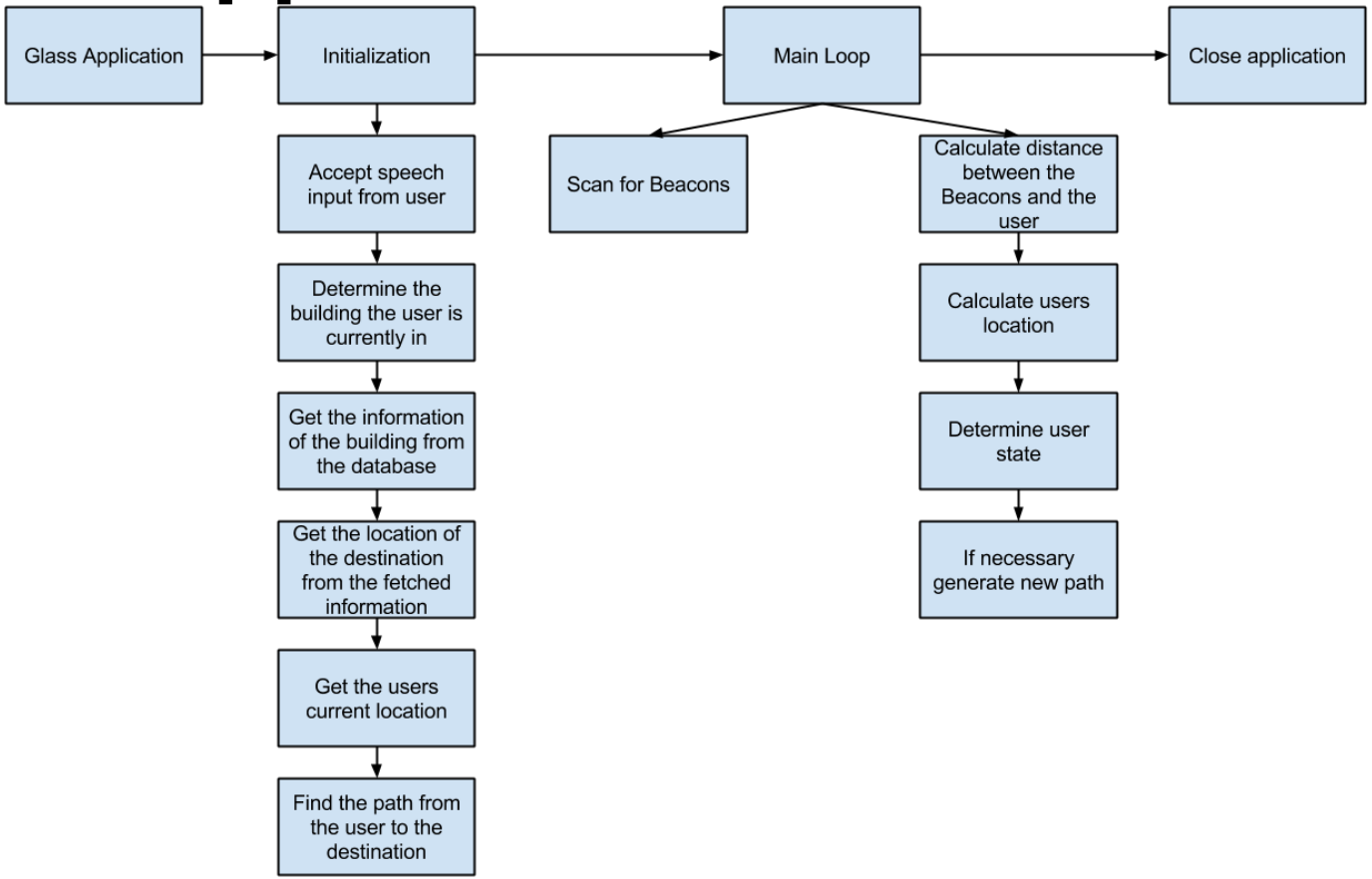
System Design



Specifications

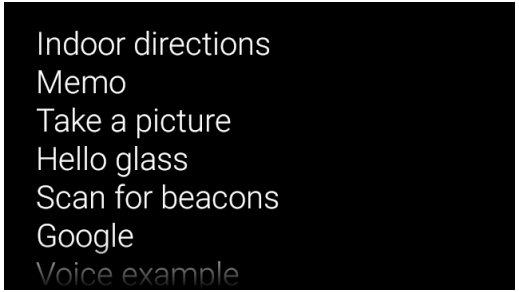
- Bluetooth 4.0 Support
  - Robust Design - support for wide range of modern handheld and wearable wireless devices
- Configurable Antenna Modes - Omnidirectional or Unidirectional
  - Unidirectionality offers potential extra power savings and/or range
- Range ~50 ft
- Supports power via 2.0-3.5 Input Voltage
- Ultra low current draw
- Photovoltaic Support
- Battery Back-up

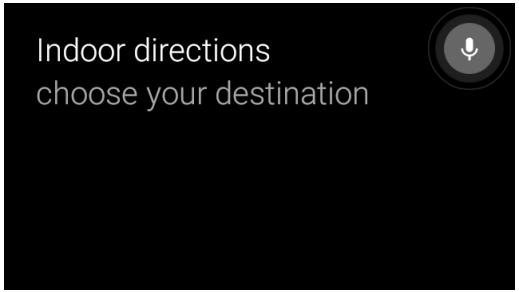
Glass Application



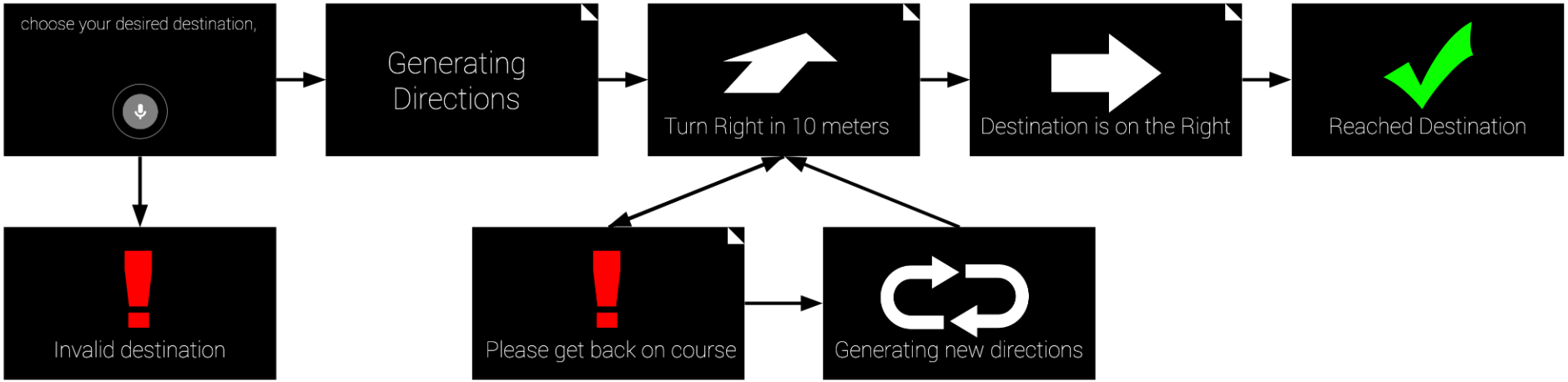
Glass Application

- In order to start the application the user will say the “ok glass” keyword to bring up the application menu
- They will then use the “indoor directions” keyword to start the application
- The user will then be prompted to speak their desired destination





Glass Application

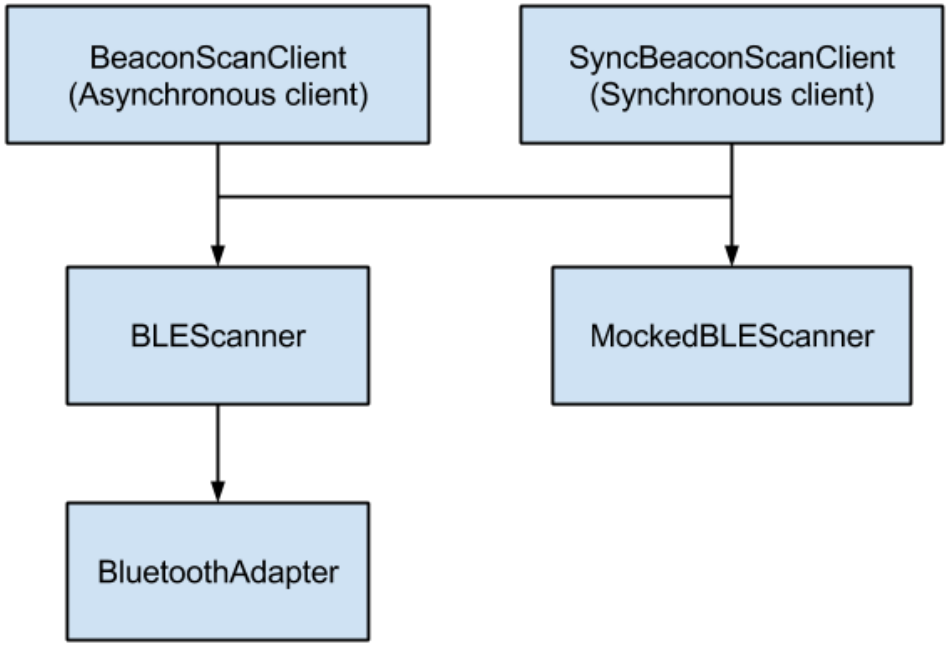


- Whenever a message is displayed on the screen it is also communicated verbally to the user
- An arrow will be displayed on the screen which will point to the next waypoint

- A wakelock is going to be applied while the application is running so the device won't turn off.
  - Wakelock must be properly disabled if user exits the application

Android Beacon Library

- Wrapper for Android's BluetoothAdapter
- Handles converting Androids native BluetoothDevice objects to our Beacon object
- Filters out BLE devices which aren't Beacons by parsing the signal received
- Includes a synchronous and asynchronous client



Trilateration

- Algorithm uses the approximate distances from the Bluetooth beacons that have a known position to calculate the user's location in the building

- Least-squares solution that only requires linear algebraic operations
  - Algorithm used from article in the IEEE Xplore Library

- Can only determine an approximate location and not the exact location of the user
  - With greater varying distance measurements comes greater inaccuracy
  - With more distance measurements from more beacons comes greater accuracy due to summations of the distances within the algorithm

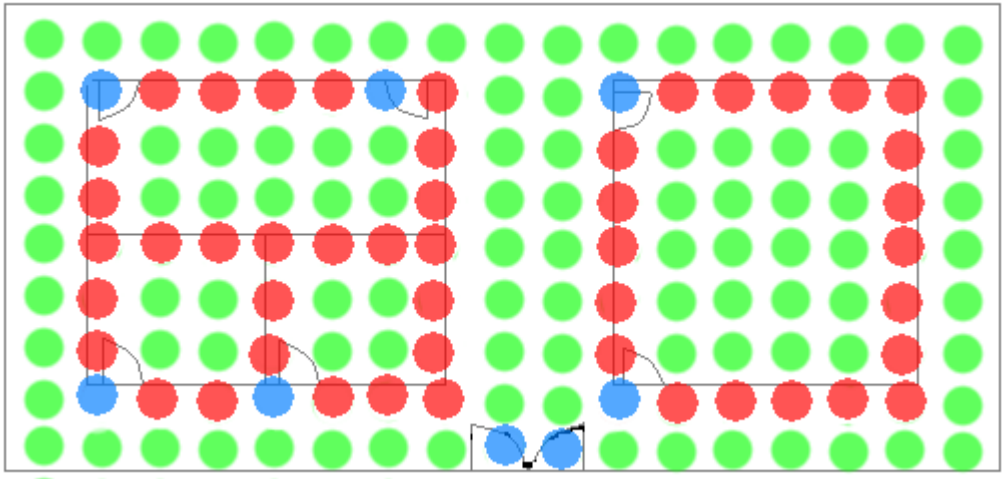
Pathfinding

- Constructs a path between the user's location and destination using virtual nodes that describe the building's layout

Green: Walkable areas

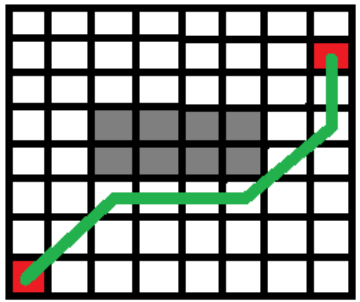
Red: Blocked areas

Blue: Possible destinations

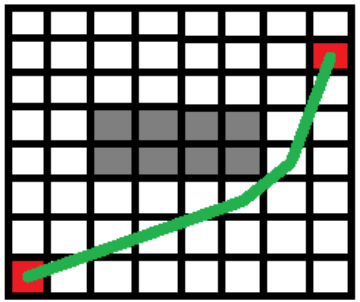


Pathfinding

- Uses Theta* instead of A* for pathfinding on each floor
- Theta* calculates paths with fewer turns allowing for simpler directions because the algorithm incorporates line of sight when determining the path

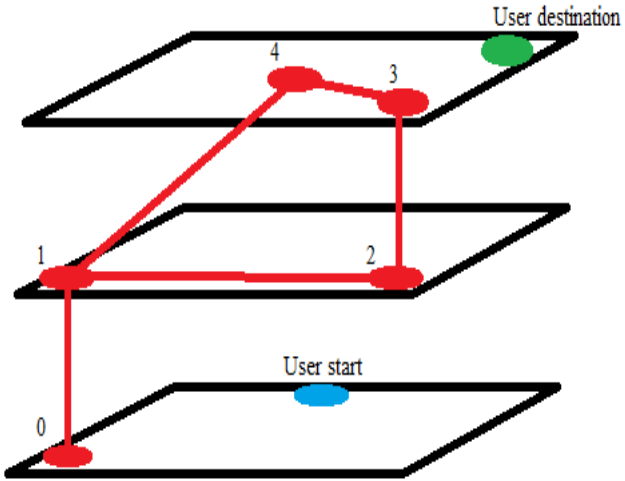


A* Algorithm



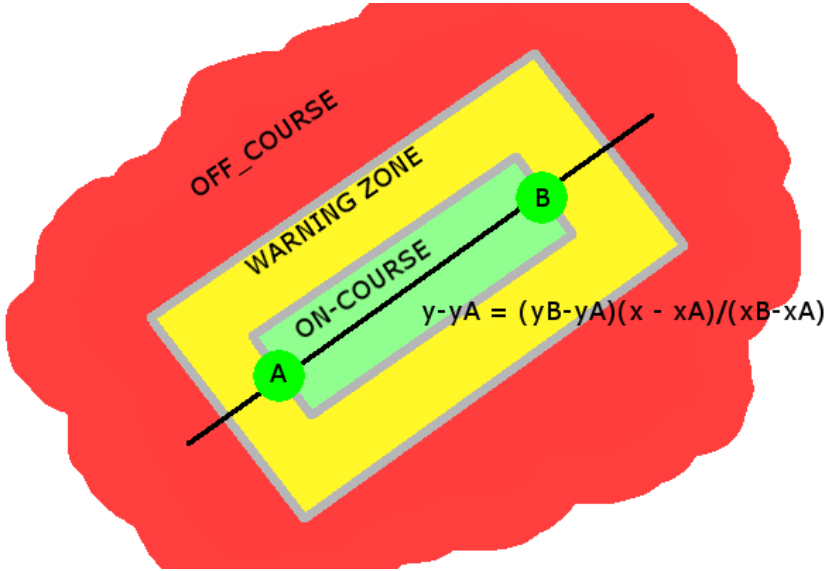
Theta* Algorithm

Floor Sequencing



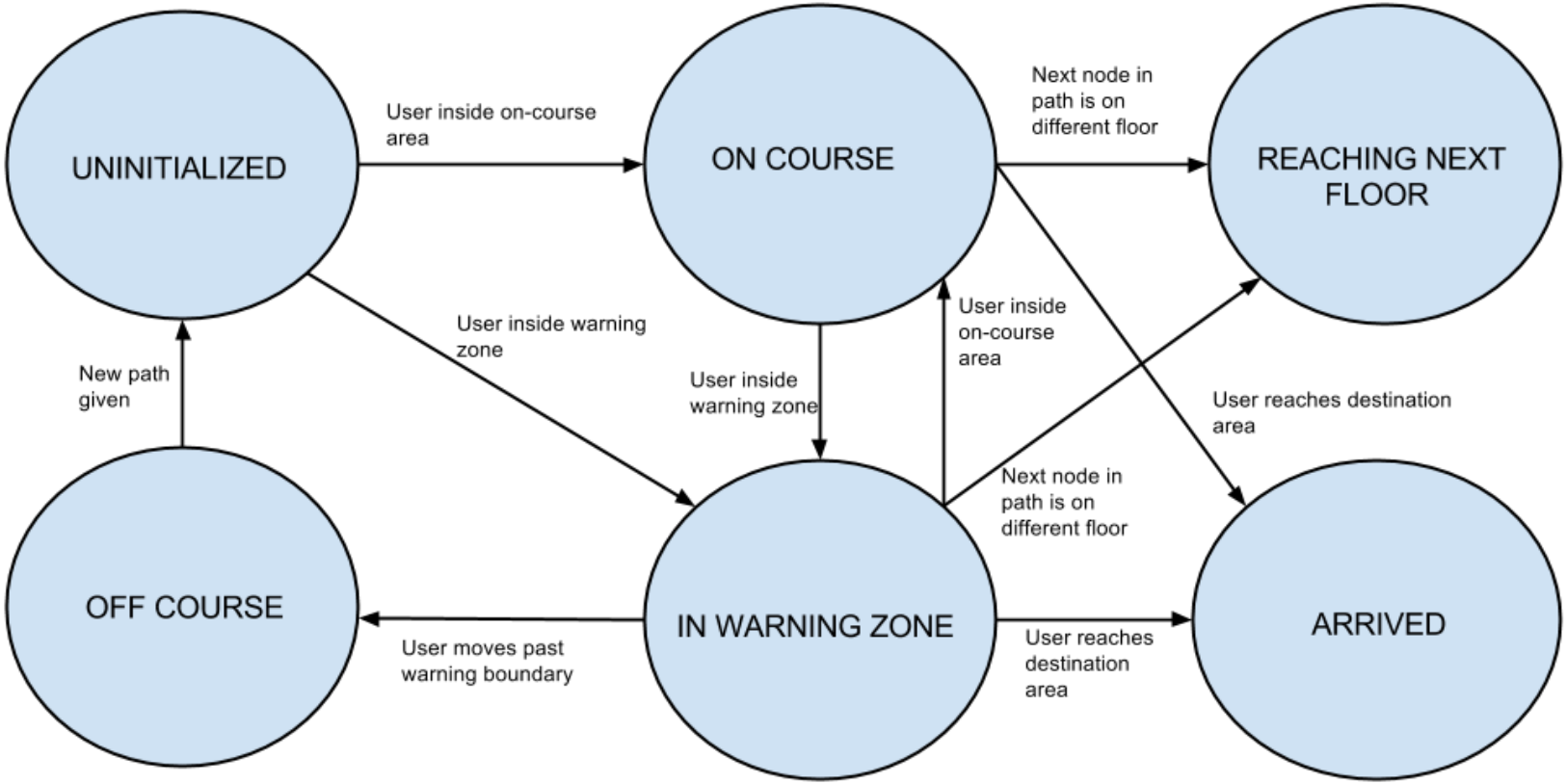
- Handles path planning across multiple floors when the user's destination is on a different floor
  - Links the paths calculated from Theta* together into one multi-floor path
  - Uses an adjacency list holding the connections between floors to link the single floor paths
  - Basic process:
    - Use depth-first search to get all possible ways to get to the destination floor
    - Link together Theta* paths into one multi-floor path

User State Tracking



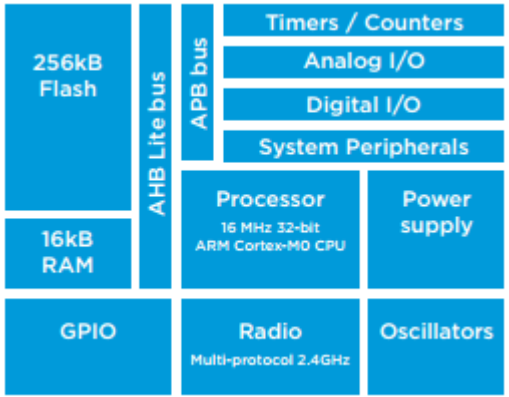
- Determines whether the user is on-course, off-course, or in the warning zone
- The nodes in the Floor Sequencer path are used to generate two rectangular boundaries
  - Boundaries wrap around the previous path node the user passed and the next node in the path they need to reach
- The user state is then reported to the system to adjust accordingly

User State Tracking



nRF51822

- “System on Chip”
- 48 pins QFN package
- Compact form factor
- Low power consumption
- 2.0-3.5 volts supply requirement
- Integrated 2.4 Ghz transceiver
- Bluetooth 4.0 LE or ANT support
- Integrated UART
- 31 GPIO



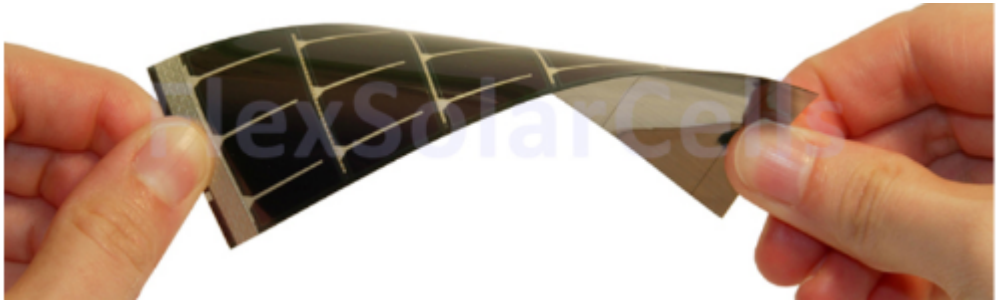
nRF 51822 Product Specifications Datasheet (http://www.100y.com.tw/pdf_file/39-Nordic-NRF51822.pdf)

Power

- Solar
- DC
- AC

Solar Cell

- MP3-37
- Primary source
- 3.0 Volts
- Flexible



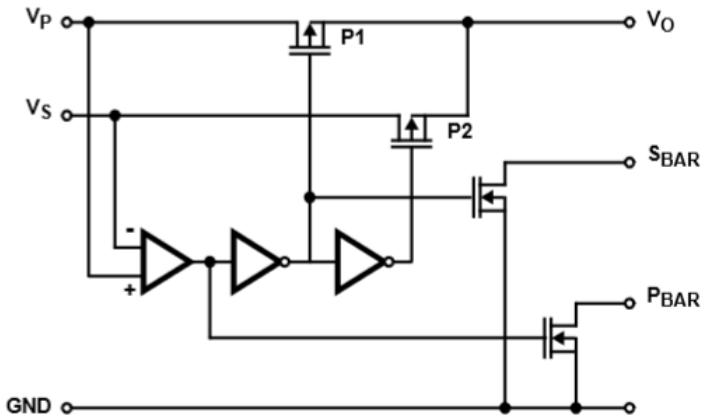
http://www.flexsolarcells.com/index_files/OEM_Components/Flex_Cells/pages/03-PowerFilm-Solar-Cell-Module-MP3-37.php

Battery

- Secondary source
- 3.0 volts
- LIR2450
- 2032BP

Battery Management

- ICL7673
- CMOS circuit
- 3v battery backup
- If solar power source is lost, connects to battery
- Reconnects to main power when restored
- p>s, primary source
- s>p, secondary source



ICL7673 Datasheet http://www.mouser.com/ds/2/465/fn3183-70450.pdf

Crystal Oscillator Circuit

- nRF51822 SoC requires an external oscillator crystal circuit
- Capacitors in the crystal network must match

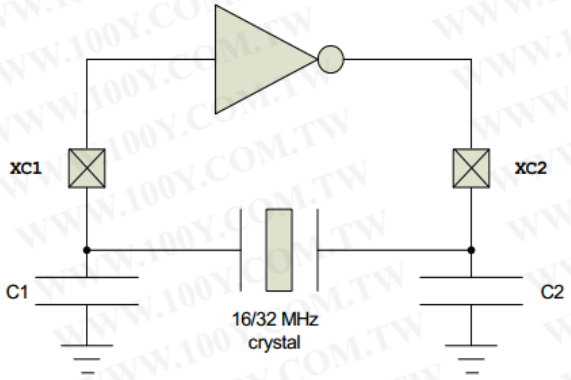


Figure 6 Circuit diagram of the 16/32 MHz crystal oscillator

The load capacitance (CL) is the total capacitance seen by the crystal across its terminals and is given by:

$$CL = \frac{(C1' \cdot C2')}{(C1' + C2')}$$

$$C1' = C1 + C\_pcb1 + C\_pin$$

$$C2' = C2 + C\_pcb2 + C\_pin$$

nRF 51822 Product Specifications Datasheet (http://www.100y.com.tw/pdf_file/39-Nordic-NRF51822.pdf)

Radio Scheme

- Antenna Diversity via Switch
  - Omnidirectional Antenna
  - Unidirectional Antenna
- Switchable antenna allows for optimal coverage in a variety of scenarios; provides for a robust platform
- RF Switch IC AS169-73LF

Unidirectional Antenna

- Offers radiation pattern in one direction
- TI reference design on the right requires 4-layer PCB
- Yagi PCB antenna

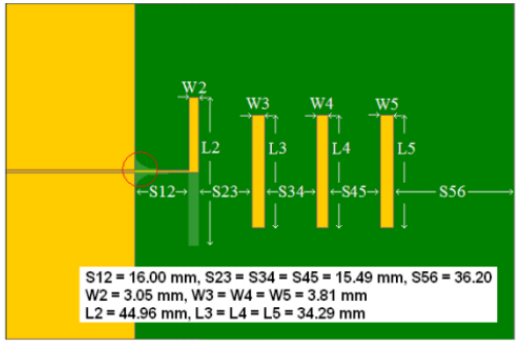


Figure 2. 2.4 GHz Yagi PCB Directional Antenna Dimensions

Omnidirectional Antenna

- Radiation pattern spreads to all directions
- TI reference design requires 2-layer PCB
- Inverted F-antenna PCB

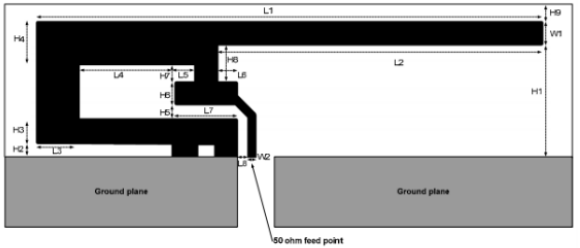


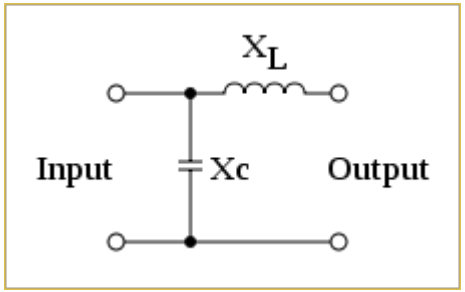
Figure 1. IFA Dimensions

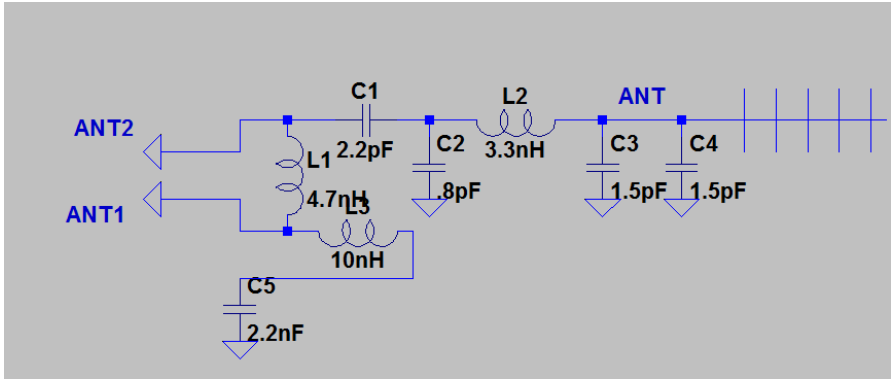
H1	5.70 mm	W2	0.46 mm
H2	0.74 mm	L1	25.58 mm
H3	1.29 mm	L2	16.40 mm
H4	2.21 mm	L3	2.18 mm
H5	0.66 mm	L4	4.80 mm
H6	1.21 mm	L5	1.00 mm
H7	0.80 mm	L6	1.00 mm
H8	1.80 mm	L7	3.20 mm
H9	0.61 mm	L8	0.45 mm
W1	1.21 mm		

Table 1. IFA Dimensions

Antenna Impedance Matching

- Pi Matching Network
- Physically trim antenna on pcb
- Potential alternative for future iterations: balun and a matching chip antenna - more compact and easier to implement
- Trace Width is an important consideration: match 50 Ohms impedance; AppCAD PCB trace width





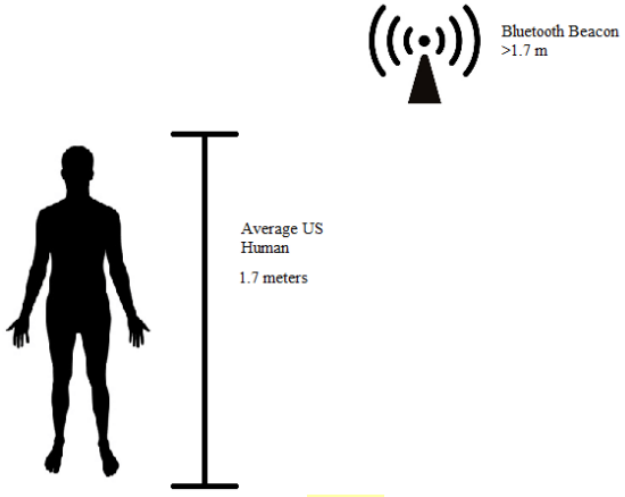
PCB design

4-Layer	2-Layer
More expensive	Cheaper
Allows for a more compact design	Requires more space

- Mainboard will house: Xtal circuit, power supply circuit, antenna circuit, I/O
- Considerations:
  - PCB tracing sensitive to electromagnetic interference from other components and traces on board e.g. 4pcb known to etch make number of boards which can cause interference with nearby antenna trace elements via stray capacitance
  - Keep layers underneath antenna circuitry clear of traces
  - Avoid long traces for power

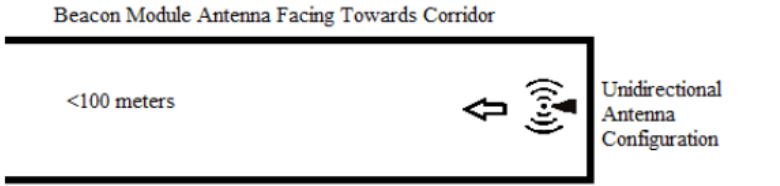
Beacon Placement Optimization

- Situation Area: Engineering 1
- Placement height: >1.7m
- Possible Locations:
  - Ceiling
  - Wall
- Avoid nearby RF interference (e.g. microwave ovens)

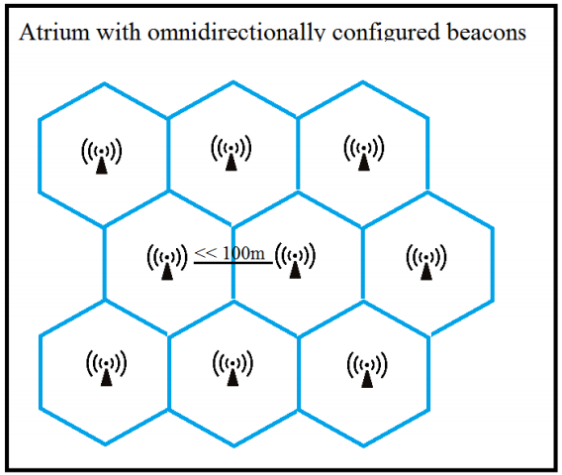


Beacon Placement Optimization

- The max operating range of typical bluetooth devices is limited
- Omnidirectional antenna placement in large open spaces
- Unidirectional antenna placement at end of corridors or corners

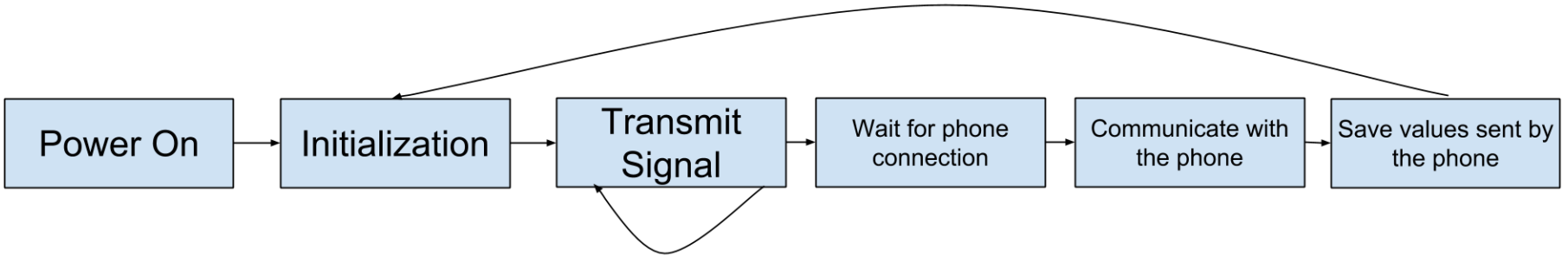


The above figure shown demonstrates the proper beacon placement of a unidirectional antenna in a long corridor



The above figure shows the hexagonal tiling configuration on beacon modules in a large, indoor open space

Beacon Firmware



Challenges Ahead

- Handling imprecise beacon signal readings
  - Smoothing distance readings, constructing a line of best fit
  - Beacon broadcast rate: increasing the number of signal samples transmitted and received

- PCB considerations: 2-layer vs 4-layers

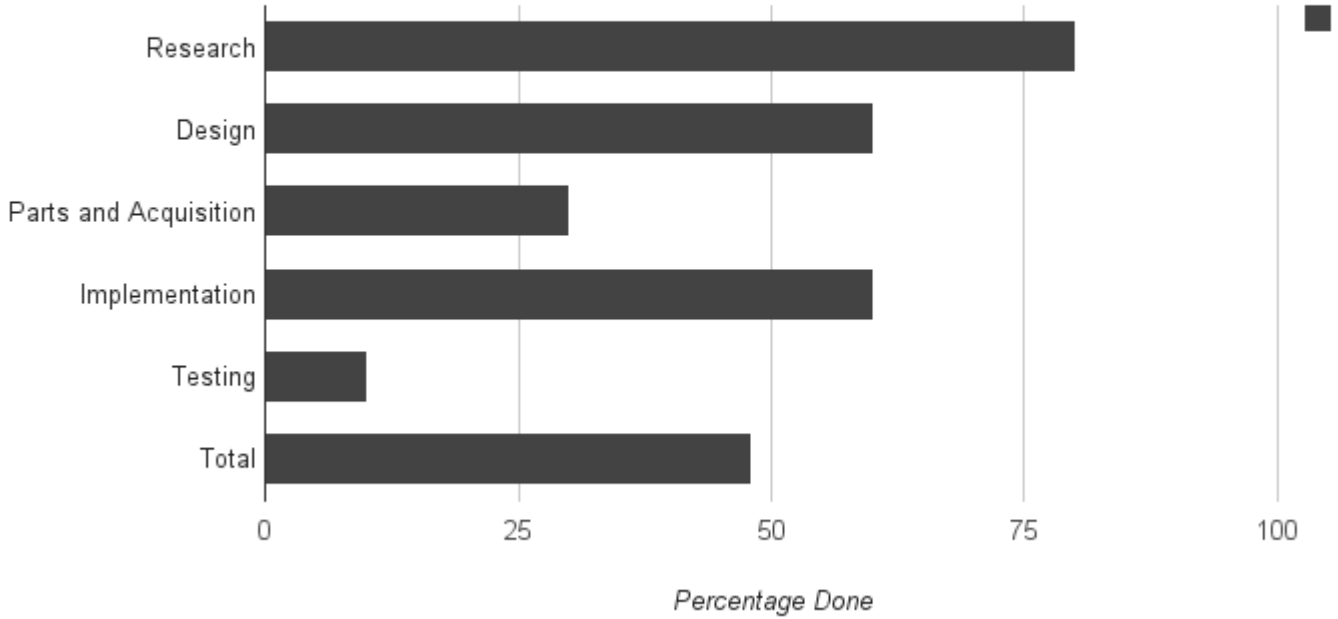
- SMT and QFN mounting

Bill of Materials

Budget: $750
Money Spent to date: $149

Product	Quantity	Price	Status: obtained
Smart Beacon by Nordic	1	$31.95	
Nordic Development kit	1	$99	
Google glass	1	Previously Owned	
Solar cell	10	$55.60	
QFN 48-pin breakout testing board	3	$5.95	
Crystals, capacitors, resistors	many	$12.20	
2 digit display	1	$3	
2 layer PCB		$33 ea	
nRF51822 nordic chip	10		
Rechargeable cell battery LIR2450	5	$15	
ICL7673	5	$15	
AS169-73LF	5	$10	

Development Progress



Workload Distribution

Members	Josh	Jonathan	Pedro	Andre
Pathfinding	X			
Trilateration	X			
User state tracker	X			
Beacon Library				X
Glass Application				X
Configuration Application				X
Power Design			X	
Antenna and RF design		X		
I/O Interface Design		X	X	
Beacon Firmware		X	X	

Fragen?

Вопросы есть?

Questions?

¿Preguntas?