Deliverable D - Conceptual Design

Group P10

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Abstract

In order to develop a set of conceptual designs for the client, Shabodi, we look at previously outlined user benchmarking, technical benchmarking and a prioritized list of design criteria. These concepts are analyzed and evaluated, and consequently narrowed down according to various factors such as the aforementioned.

Table of Contents

1 Introduction 5

1.1 Problem Statement 5

2 Idea Generation 5

2.1 Ideas for Subsystem 1 5

2.2 Ideas for Subsystem 2 9

2.3 Ideas for Subsystem 3 11

3 Final solutions 14

3.1 Solution 1 14

3.2 Solution 2 15

3.3 Solution 3 16

3.4 Chosen Global Concept 17

4 Conclusion 17

5 Future Work 18

6 References 19

1 Introduction

Based on the problem statement (1.1), as well as benchmarking and design criteria outlined in Deliverables B and C, various concepts will be generated for relevant subsystems

1.1 Problem Statement

"Enterprises in industries such as manufacturing require network-aware applications that can dynamically control devices and adapt to varying network conditions. These applications must deliver real-time, low-latency performance, prioritize functionality over aesthetics, and leverage Shabodi's platform to solve practical, business-critical challenges quickly through iterative development cycles." [1][2]

2 Idea Generation

The Restricted zone alerting project proposed by Shabodi must perform various tasks specified by the client, such as "alert the network administrator if an unauthorized UE [User equipment] enters a restricted zone", "provide the network administrator with the UE's location for further investigation" and "record and store all information related to the unauthorized access event" [3]. Therefore, to accommodate the various functionalities of the product, the project can be divided into three main subsystems: Location detection; Information Processing/Storage; System Response.

2.1 Ideas for Subsystem 1 - Location detection

The first subsystem, location detection, will utilize Shabodi's APIs to acquire the location of the UE. Various methods can be used, such as those found during technical benchmarking [2], and the goal of this subsystem is purely to obtain a position in space in a manner that fulfills the design criteria [1][2]. Below is a list of concepts for the location detection mechanism:

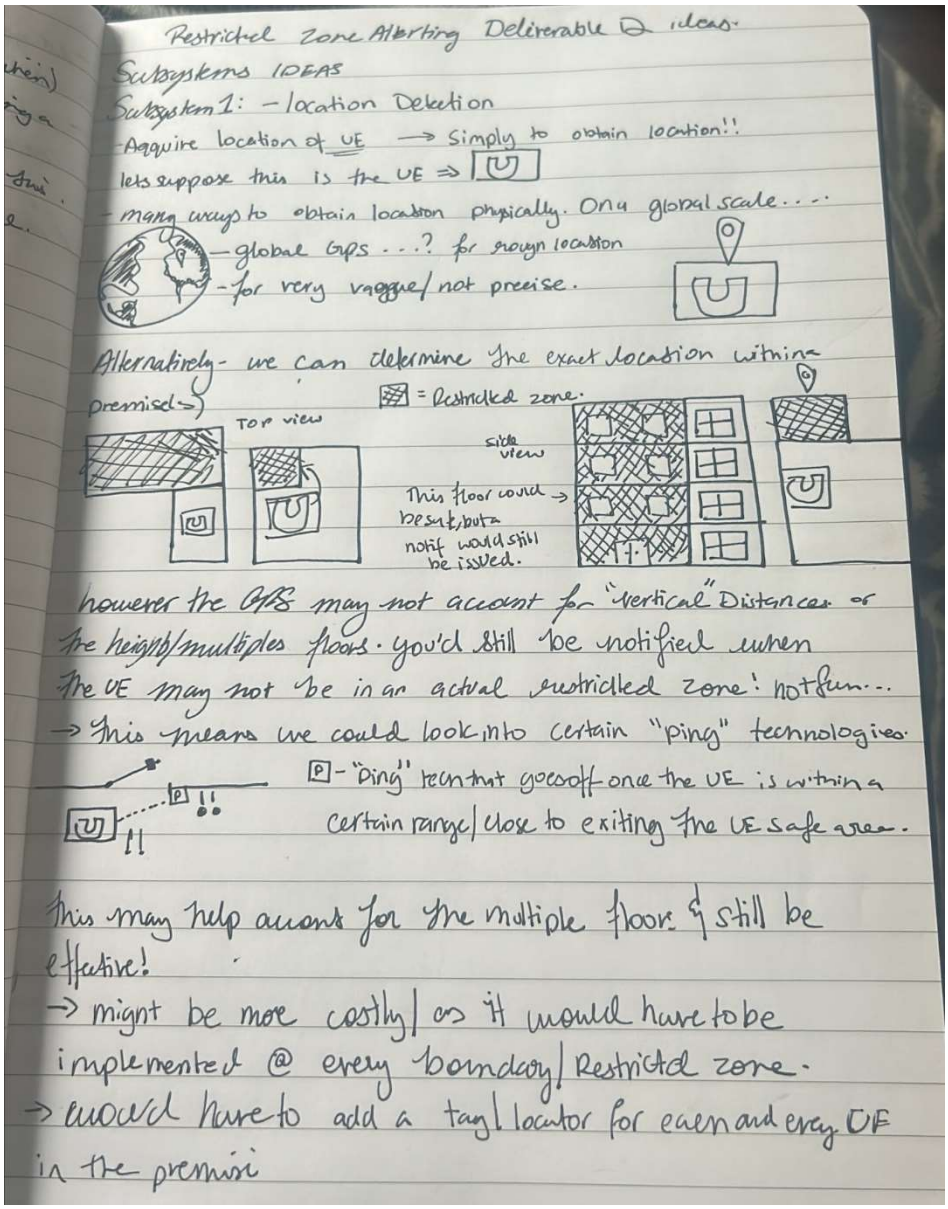


Figure 1: Subsystem 1 Concept designed by Manasvi Khanna

Advantages for this concept:

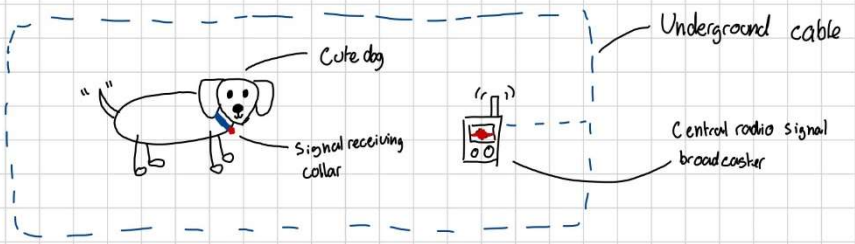
1. Accounts for the “vertical” distances as well as horizontal, meaning that it will provide accurate data for buildings with multiple floors.
2. Provides real-time data consistently.

Drawbacks for this concept:

1. May be more costly, as it would have to be implemented at ever boundary/restricted zone.
2. Would have to add a tag/locator for every UE in the premise.
3. Requires a final solution that is both software and hardware—once again, may prove more costly.

PD.D Subsystem 1 Idea

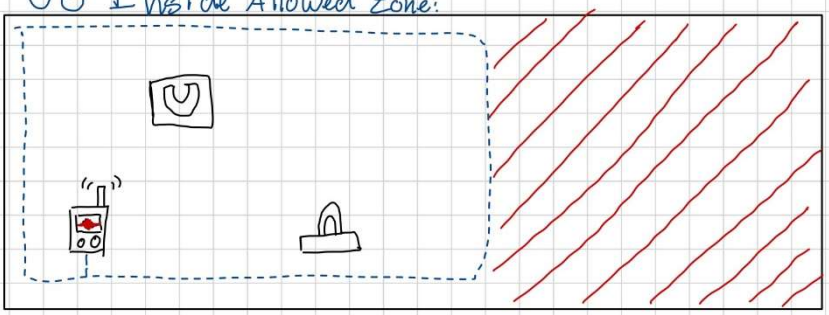
Inspiration:



During technical benchmarking, for in-close UE zone restricting we looked at "invisible" fences for dogs. These fences use radio signals transmitted by a central broadcasting "control panel" that travel along an underground cable creating a signal field outside the boundary of of the cable. When the collar, which is a computerized signal reciever, crosses into the signal field (ie: out of the boundary) it will execute a certain predetermined output like an audio cue or small shock.

Application:

UE Inside Allowed Zone:



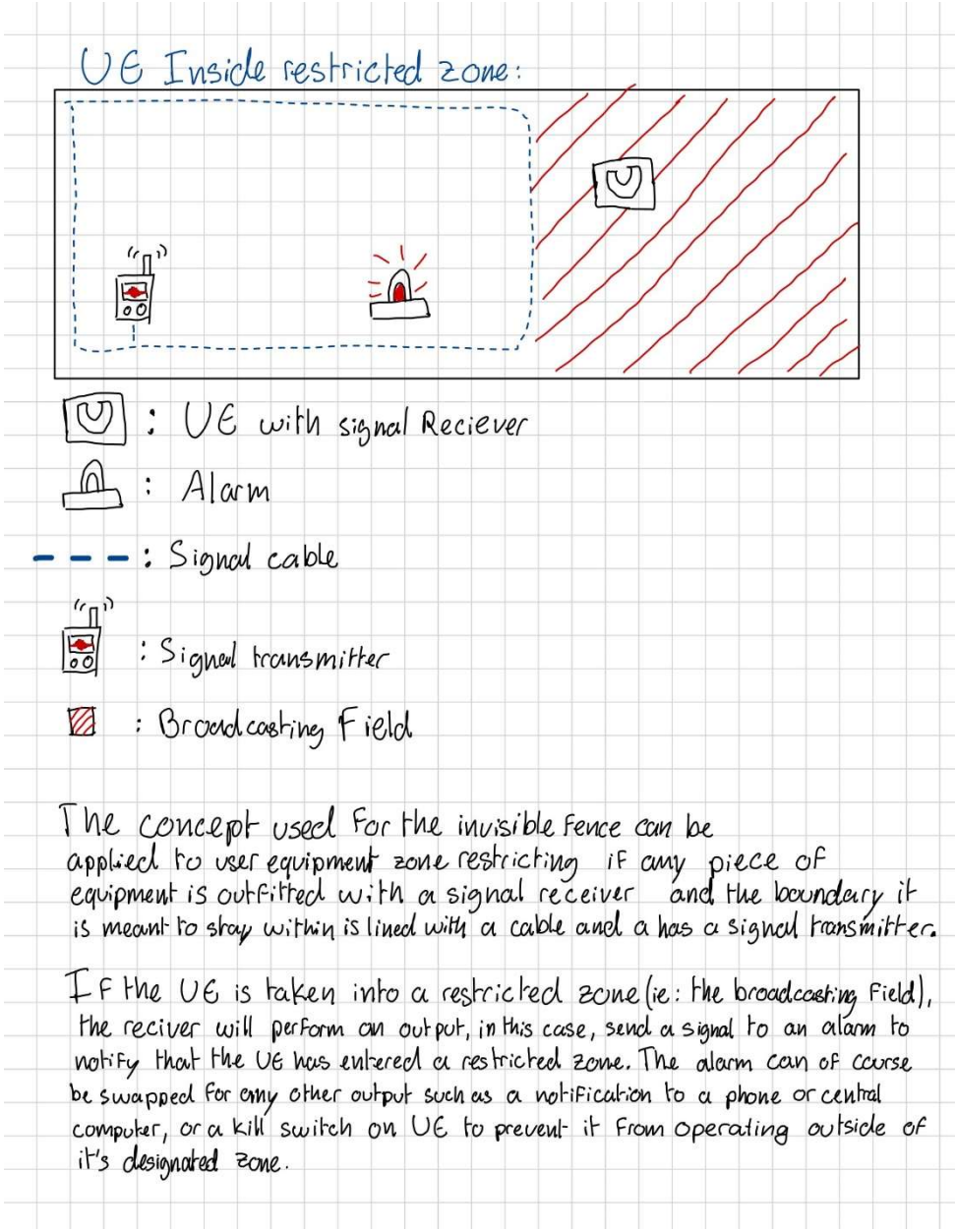


Figure 2: Subsystem 1 Concept designed by Conor Waldron

Advantages for this concept:

1. Does not require GPS or general location services that would intake a vast quantity of data, i.e. comparing one point on the globe with a proportionally smaller area of the globe, meaning that the process will prove to be faster and more efficient.

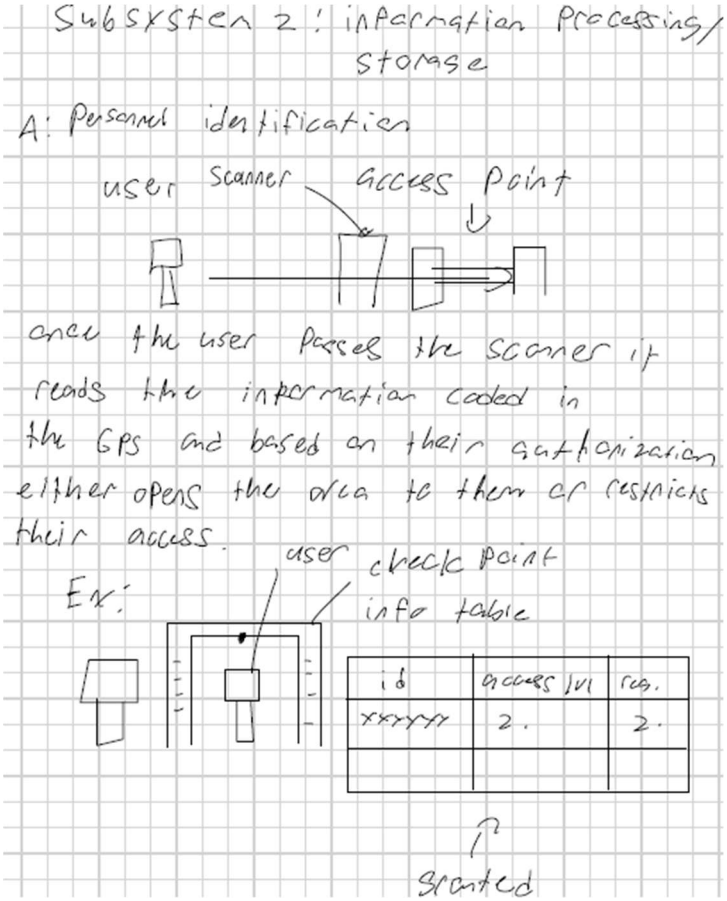
2. Can be applied to any UE, regardless of its size or shape.

Drawbacks for this concept:

1. May be more costly, as it would have to be implemented at ever boundary/restricted zone.
2. Would have to add a tag/locator for every UE in the premise.
3. Requires a final solution that is both software and hardware—once again, may prove more costly.

2.2 Ideas for Subsystem 2 - Information Processing/Storage

The second subsystem, information processing and storage, will treat the information previously obtained by the first subsystem. This may include data analysis, comparison with existing databases or compilation of the obtained information into a database. Below is a list of concepts for the information processing/storage procedure:



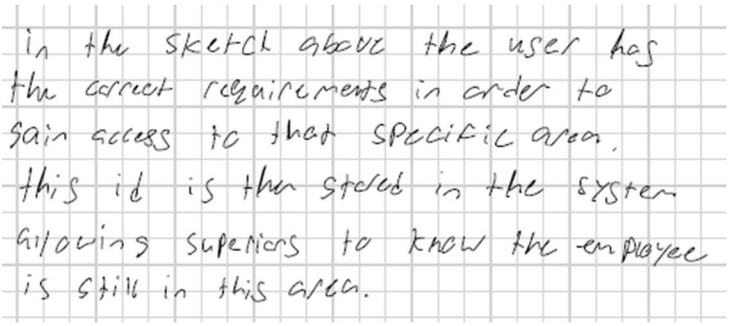


Figure 3: Subsystem 2 Concept designed by Colby Giberson

Advantages for this concept:

1. Compares location values gathered with a database that can evolve or be modified to the user's liking.

Drawbacks for this concept:

1. Use of a large database may provide errors or be difficult to troubleshoot if the system malfunctions.
2. Requires the initial generation of the database, which may be time-consuming for the users.

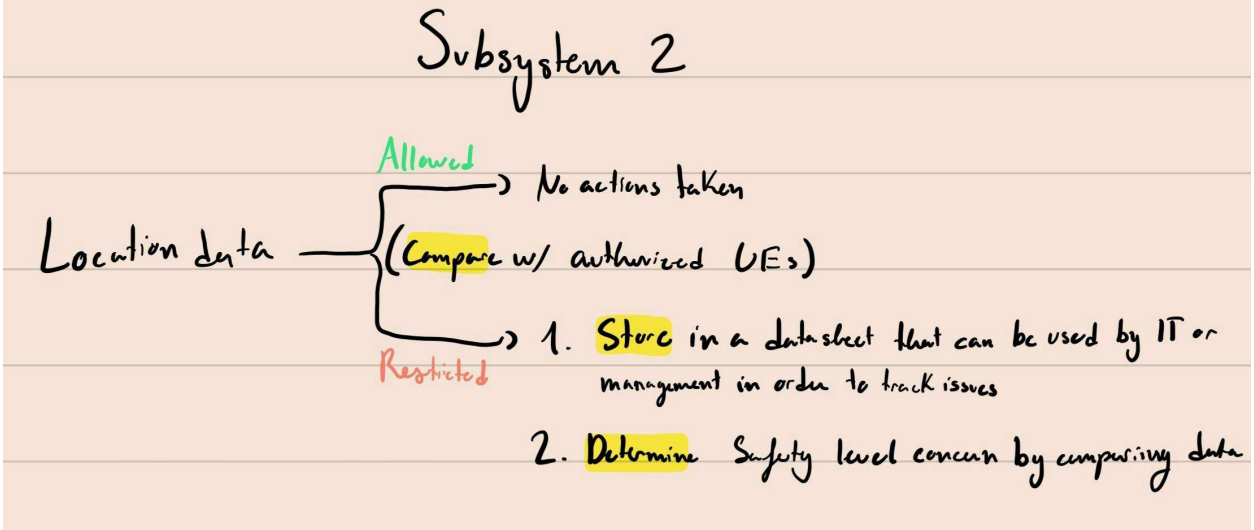


Figure 4: Subsystem 2 Concept designed by Colby Giberson

Advantages for this concept:

1. Compares location values gathered with a database that can evolve or be modified to the user's liking.
2. Stores the collected data to notify management or superiors as to the movement of the UEs.

Drawbacks for this concept:

1. Use of a large database may provide errors or be difficult to troubleshoot if the system malfunctions.
2. Requires the initial generation of the database, which may be time-consuming for the users.

2.3 Ideas for Subsystem 3 - System Response

The third subsystem, system response, will be the action taken based on the processing done in the previous subsystem. It will use the interpreted data to respond to the location of the UE obtained in subsystem 1. Below is a list of concepts for the system response mechanism:

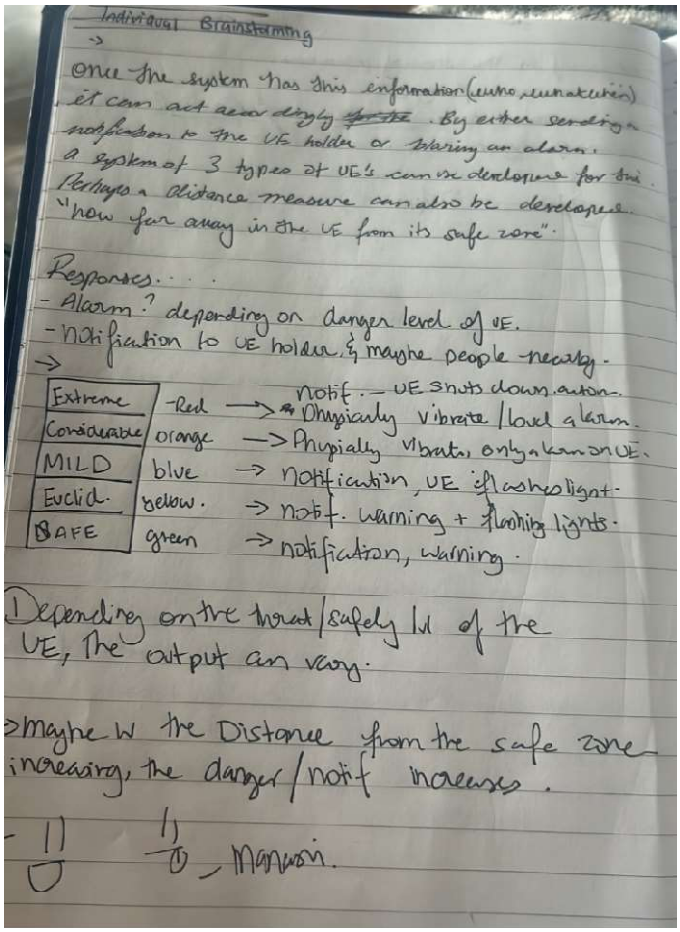


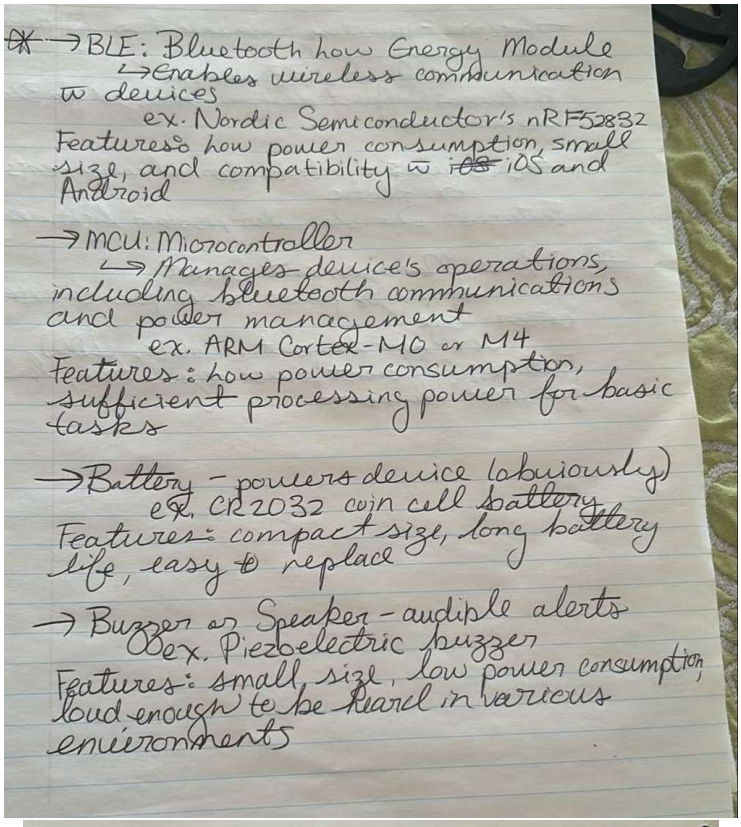
Figure 5: Subsystem 3 Concept designed by Manasvi Khanna

Advantages for this concept:

1. Provides a range of responses according to danger level, as specified by Shabodi [3].
2. Includes an external notification to immediate surroundings in case of emergency.
3. Safety range can be specified by the user.

Drawbacks for this concept:

1. Physical actions must be taken, such as vibration or alarms, which may not already be integrated into the UEs.

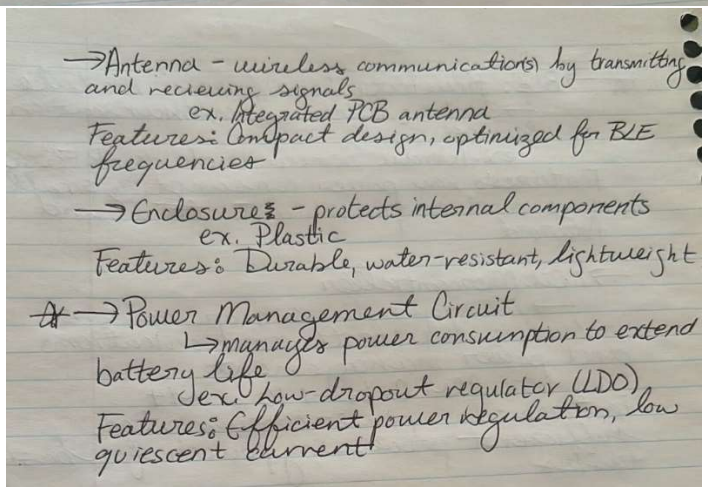


→ BLE: Bluetooth low Energy Module
↳ Enables wireless communication w devices
ex. Nordic Semiconductor's nRF52832
Features: low power consumption, small size, and compatibility w ~~iOS~~ iOS and Android

→ MCU: Microcontroller
↳ Manages device's operations, including bluetooth communications and power management
ex. ARM Cortex-M0 or M4
Features: low power consumption, sufficient processing power for basic tasks

→ Battery - powers device (obviously)
ex. CR2032 coin cell battery
Features: compact size, long battery life, easy to replace

→ Buzzer or Speaker - audible alerts
ex. Piezoelectric buzzer
Features: small size, low power consumption, loud enough to be heard in various environments



→ Antenna - wireless communication(s) by transmitting and recieving signals
ex. Integrated PCB antenna
Features: Compact design, optimized for BLE frequencies

→ Enclosure - protects internal components
ex. Plastic
Features: Durable, water-resistant, lightweight

→ Power Management Circuit
↳ manages power consumption to extend battery life
ex. Low-dropout regulator (LDO)
Features: Efficient power regulation, low quiescent current

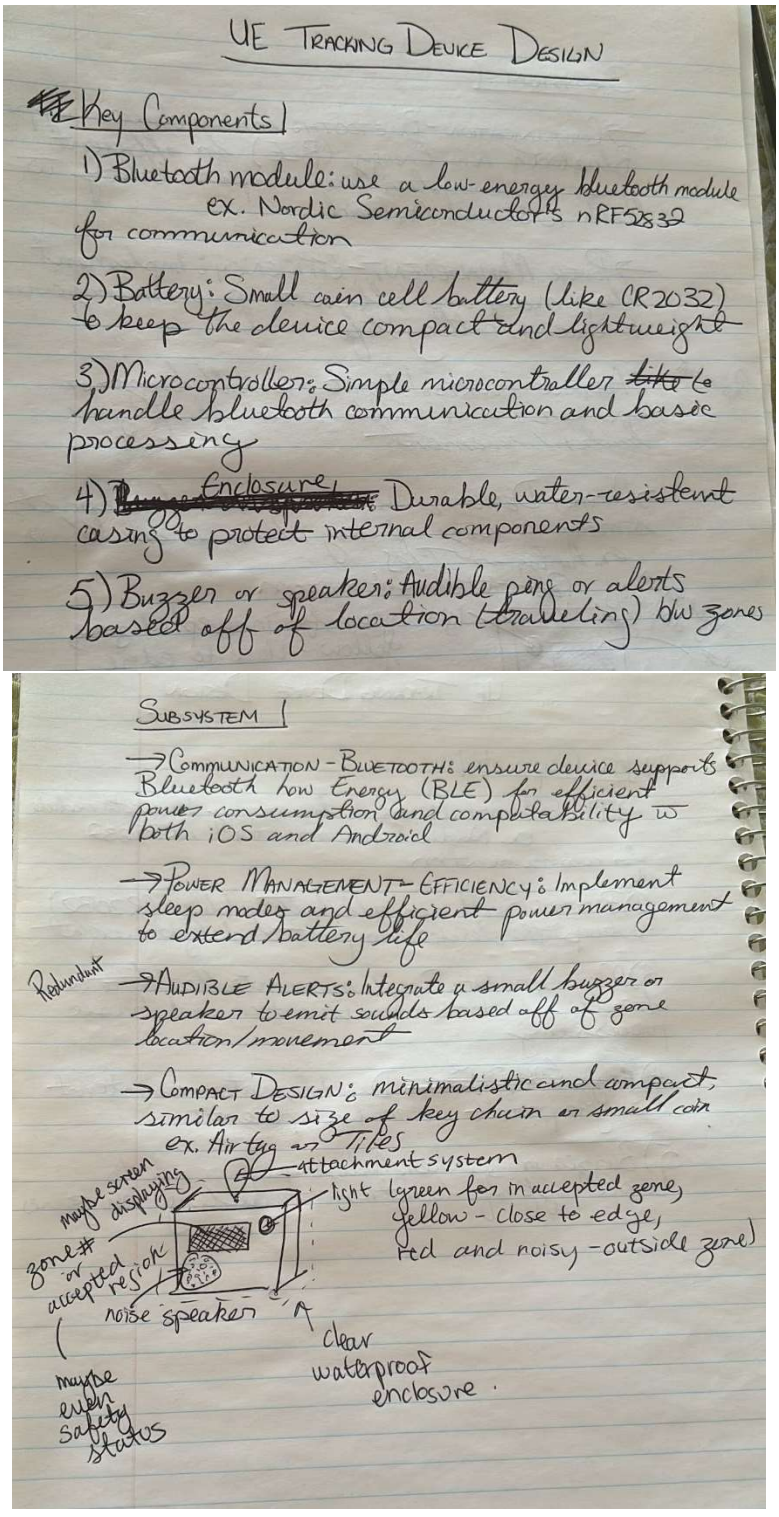


Figure 6: Subsystem 3 Concept designed by Morgan Green

Advantages for this concept:

1. Utilizes sleep-modes and maximizes efficiency in order to extend battery life.

2. Waterproof and possibly suitable for outside/more hostile environments.
3. Compact and minimalist.

Drawbacks for this concept:

1. Requires UEs to have a technical component that can be accessed via Bluetooth.
2. Runs on batteries, which need to be maintained and changed with time.
3. Information is gathered by a single box in one physical location rather than a complete system.
4. Requires a final solution that is both software and hardware— which may prove incompatible for certain situations and/or more costly in materials.

3 Final Solutions

After reconvening as a team and discussing the concepts, we were able to reorganize the subsystem concepts to produce three fully functional solutions.

3.1 Solution 1

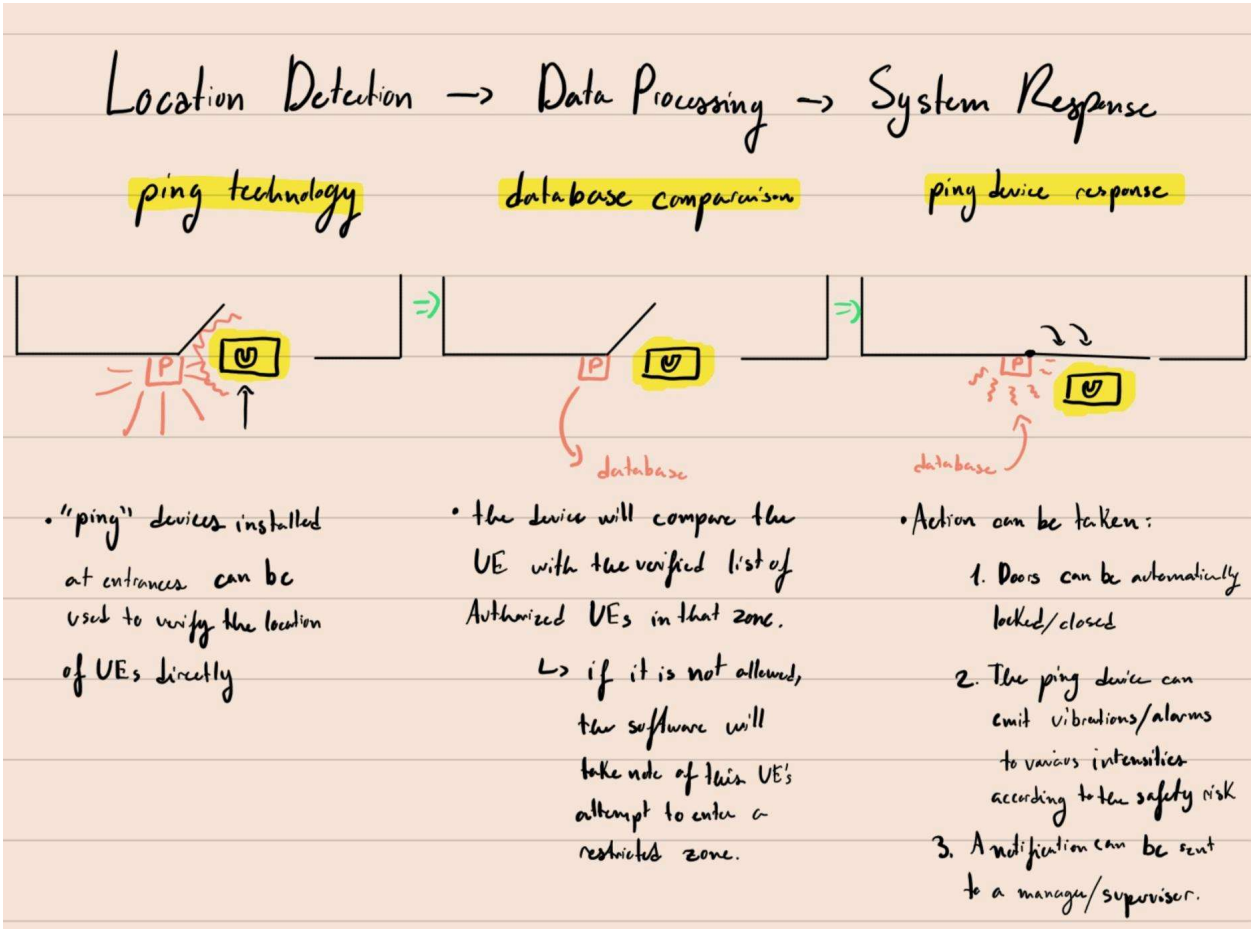


Figure 7: Solution 1

Advantages for this solution:

1. “Ping” devices can be installed uniquely in zones requiring restricted access, rather than the entire area.
2. Direct signaling for positioning prohibits the need for a GPS or larger system.
3. The ping devices can easily interact and communicate with the database created, utilizing Shabodi’s APIs for device interaction.
4. Direct actions can be taken such as locking of a physical door.
5. The ping device can include features such as an alarm or vibration feature for various levels of safety breach alerts.

Drawbacks for this solution:

1. Requires the development and installation of ping devices at every restricted zone, which is both costly and time-consuming.

3.2 Solution 2

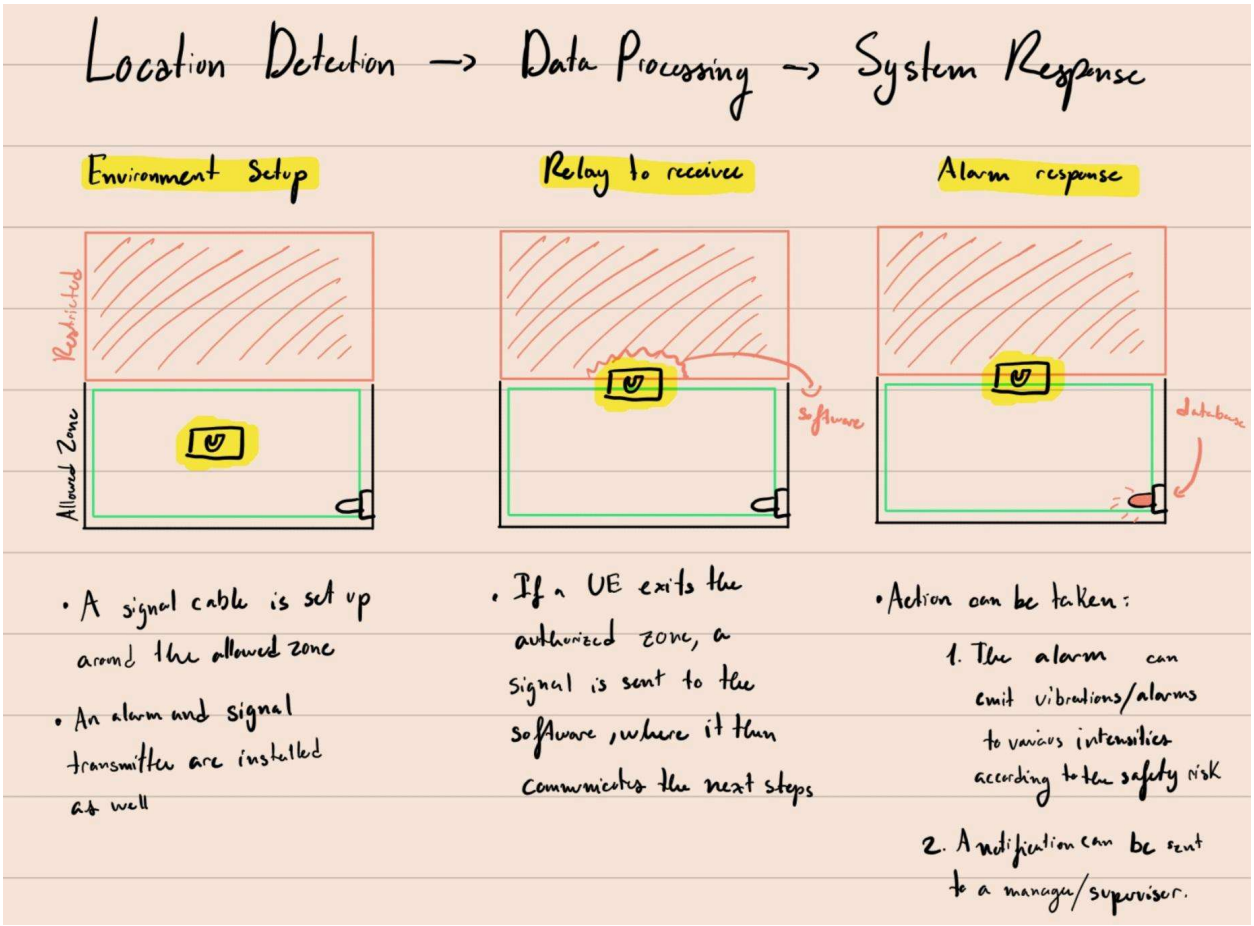


Figure 8: Solution 2

Advantages for this solution:

1. Distinct boundaries can be set, leaving very little margin for error in terms of correct zoning.

2. There is no need to compare location in coordinates with a large database, rather only compare it with a list of authorized names.
3. Direct actions can be taken by the alarm, such as an alarm or vibration feature for various levels of safety breach alerts, as well as notifications directed towards management.

Drawbacks for this solution:

1. Requires the installation of a signal cable around the allowed zone, which is laborious and costly.

3.3 Solution 3

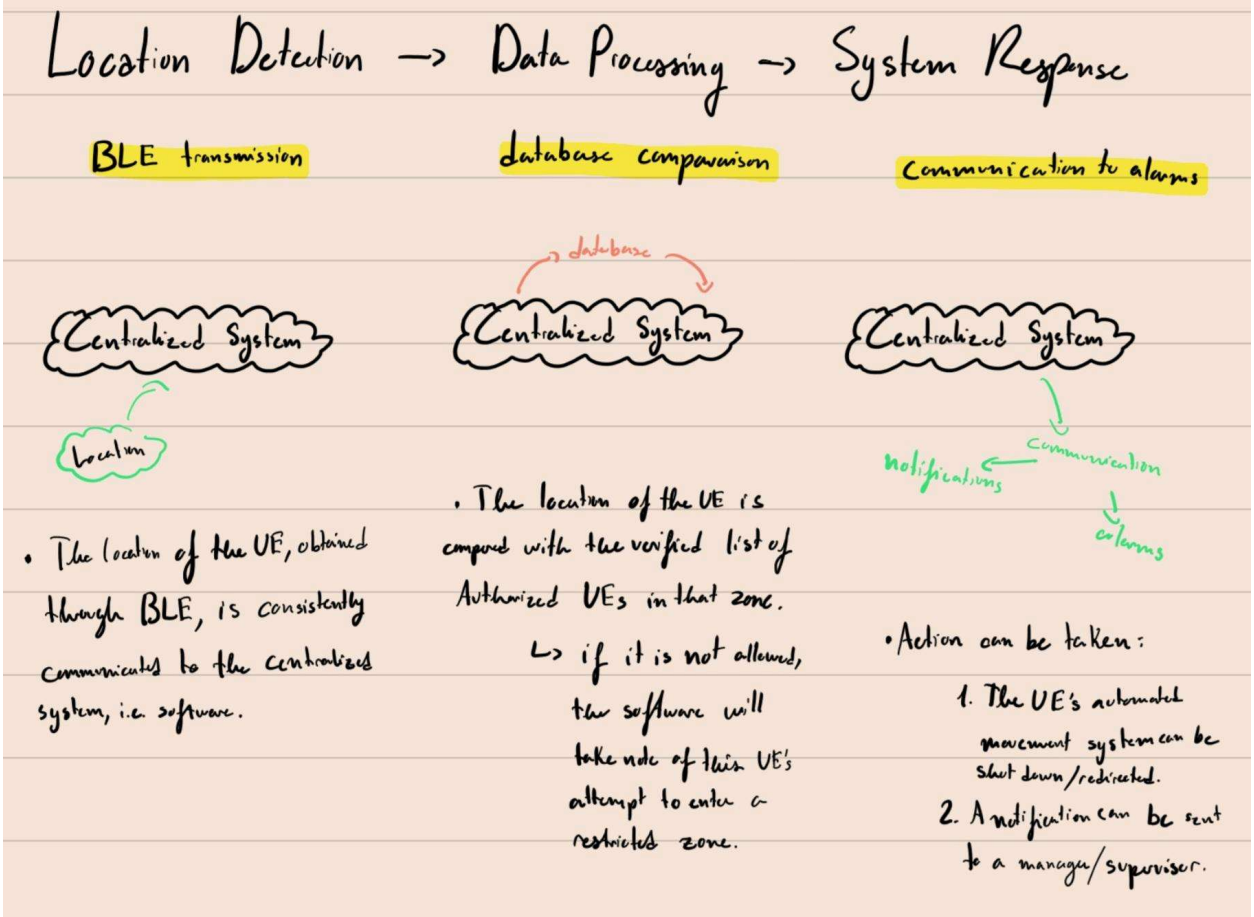


Figure 9: Solution 3

Advantages for this solution:

1. Does not rely on the presence of a physical device, rather it relies on pre-existing sensors built into the UEs which minimizes material and installation costs.
2. The location can be obtained anywhere, regardless of the boundaries of the building or physical limitations.
3. The centralized system can directly act on the automated movement of the UEs by redirecting them and/or notifying a manager.

4. The solution is flexible and can be applied and updated with relative ease.

Drawbacks for this solution:

1. Location of UEs must constantly be monitored to make sure that they have not changed within a certain timeframe, which reduces efficiency.

3.4 Chosen Global Concept

The best global concept was selected based on their performance according to the selection matrix below:

	Solution 1	Solution 2	Solution 3
Compatibility	Limited only to Shabodi's API capabilities given that we are designing the ping device	Limited only to Shabodi's API capabilities given that we are designing the signaling device	Limited only to Shabodi's API capabilities
Features	- Includes physical alarms - Database comparison - Notify supervisors	- Includes physical alarms - Database comparison - Notify supervisors	- Can include physical alarms - Database comparison - Notify supervisors
Battery Life	Depends on materials chosen	Depends on materials chosen	Unlimited (dependant on UEs)
Water Resistance	Depends on materials chosen	Depends on materials chosen	N/A
Material Cost	Moderate	High	N/A

Table 1: Selection Matrix

According to the above rotation matrix, the **third solution** is the best fit for this project.

4 Conclusions

Although many physical applications can provide a more accurate and comprehensive solution to the proposed problem, it adds another dimension to the complexity of a currently vague demand from the client, Shabodi. As specified, the client is looking for a solution that delivers real-time data, processes it and allows for efficient communication between devices. Therefore, a flexible solution that uses pre-existing features (i.e. Bluetooth) can provide a solid foundation while still allowing freedom to incorporate further functionality if time constraints, budgeting and resources allow it.

5 Future Work

The next steps include developing specific project tasks with a scheduled view to complete three project prototypes within the given timeframe, developing a Bill of Materials and budgeting for the equipment necessary for the first prototype.

6 References

1. Laila Farid, Colby Giberson, Morgan Green, Manasvi Khanna, and Connar Waldron, “Deliverable B”, 2024. Available on Brightspace Submissions.
2. Laila Farid, Colby Giberson, Morgan Green, Manasvi Khanna, and Connar Waldron, “Deliverable C”, 2024. Available on Brightspace Submissions.
3. Makerepo, “Advanced Network Applications”, *Makerepo*, 2024. Available at https://makerepo.com/project_proposals/472.advanced-network-applications