FIREFIGHTER HEALTH MONITORING NETWORK

ECE 445 Team 17 - FALL 2024

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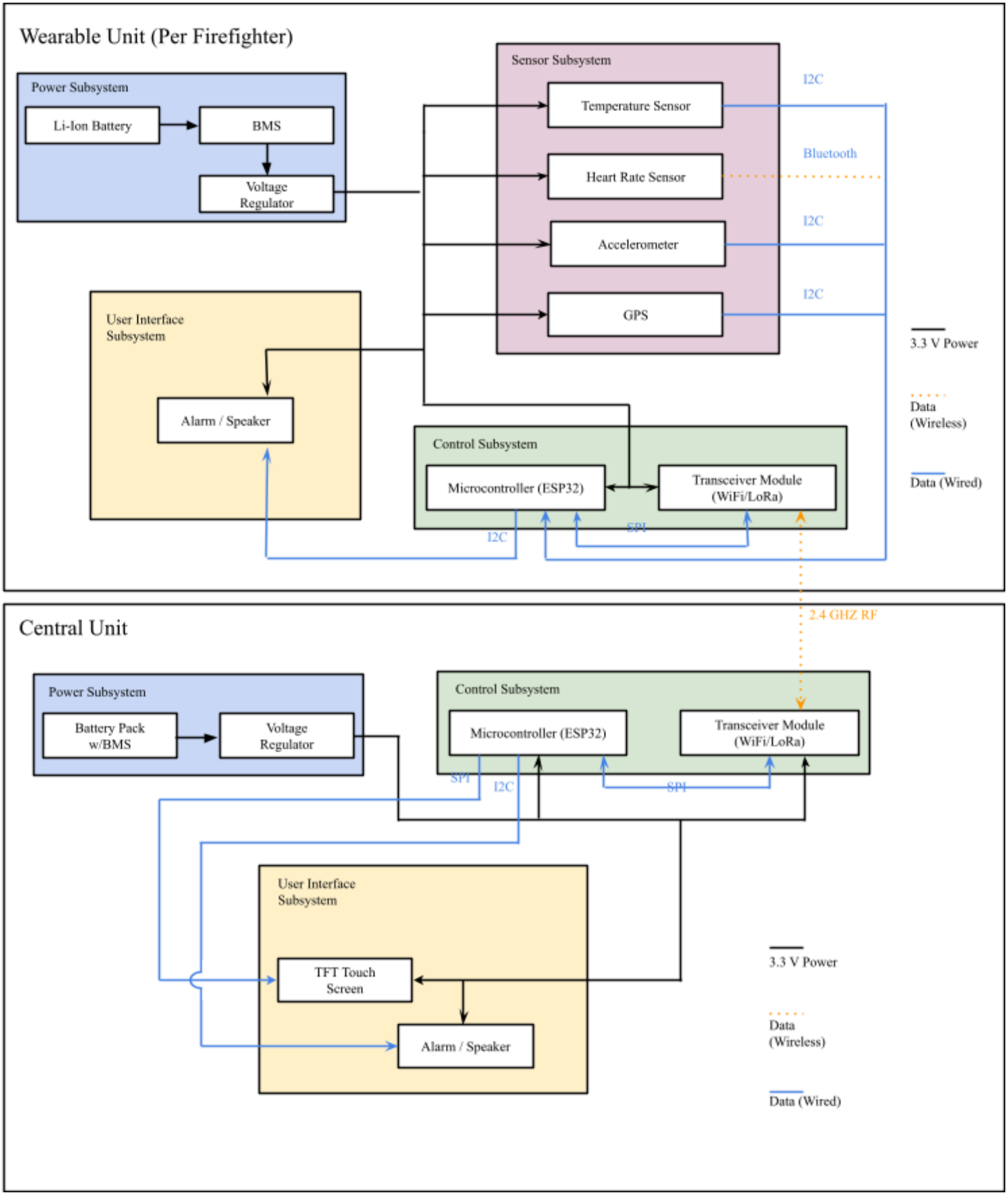
High-Level Requirements

1. The system shall continuously monitor and transmit the following data with 90% accuracy and operate on a single charge for at least 2 hours in typical fire fighting conditions above 30°C.
    a. Heart Rate
    b. GPS Location
    c. Motion Data
    d. Surrounding temperature Data
2. The system shall generate buzzer alerts on the wearable unit and central monitor within 10 seconds of abnormal detections based on thresholds on data from sensors:
    a. Heart Rate
        i. Heart rates <40 bpm or >150 bpm sustained for >30 seconds
    b. Motion Data
        i. No significant motion (Only gravity 9.8m/s^2) was detected for >60 seconds
    c. SurroundingTemperature Data
        i. Temperature exceeds 40°C for more than 3 minutes
3. The mesh network shall maintain connectivity in challenging environments with a minimum range of 250 meters in urban settings and 600m in open areas, using LoRa technology. The system shall automatically route data through multiple hops (firefighter-to-firefighter) to reach the central unit when direct communication is not possible. End-to-end data transmission time from any firefighter to the central unit shall not exceed 15 seconds, even when relaying through multiple nodes.

Block Diagram



Requirements and Verifications

Wearable Sensors Subsystem

Requirements	Verification
Wearable unit measures the surrounding temperature, heart rate, acceleration, and location of the user and sends it to the Central Monitoring Hub subsystem. • Measures heart rate with an accuracy of ±5 bpm. • Measures temperature with an accuracy of ±0.5°C. • Detects motion with a resolution of ±2m/s^2. • Detects location with a tolerance of ±20m.	1. Place a thermometer in a closed box and see if the values are the same for the device and the thermometer 2. Place the device on a person equipped with Apple Watch and validate the heartbeat 3. Place the device on a steady surface and see if the acceleration read is equal to gravity (9.8m/s^2) 4. Measure the current coordinate with phone and validate the values from the gps sensor in the wearable unit 5. Output the readings to a terminal and confirm that the central unit is reading the values in real time
Alert is generated if a firefighter's heart rate exceeds 150 bpm or falls below 40 bpm for more than 30 seconds. These thresholds account for both sustained tachycardia and bradycardia, indicating potential danger to the firefighter's health.	1. Simulate the heart rate of the wearable unit to monitor heart rates while gradually increasing to 160 bpm and decreasing to 35 bpm. 2. Validate that the wearable unit triggers an alert when heart rate exceeds 150 bpm for more than 30 seconds and when it falls below 40 bpm for the same duration. 3. Record response times and ensure alerts are activated correctly.
Alert is generated when the temperature exceeds 40°C for more than 3 minutes.	1. Place the device nearby a stove (or controlled heat source) to gradually increase the temperature around the wearable unit. 2. Monitor the wearable unit's temperature sensor and record readings. 3. Validate that the wearable unit triggers an alert when the temperature exceeds 40°C for more than 3 continuous minutes.

Alert is generated if no significant movement is detected on the firefighter for over 60 seconds.	1. Secure the wearable unit to a stationary object or user. 2. Ensure that no movement is detected (within a calibrated margin) for a continuous period of 60 seconds, and verify that an alert is triggered at that moment. 3. Test with varying degrees of movement to ensure the threshold for "significant movement" is correctly calibrated.
In emergency situations where one or more alerts have been triggered, the GPS update frequency increases from every 30 seconds to every 5 seconds.	1. Trigger one of the alerts (heart rate, temperature, or motion) while monitoring the GPS update frequency. 2. Have the person wearing the monitoring unit be continuously moving. 3. Record the GPS update intervals to verify that the unit updates every 5 seconds during an alert condition.
Reset the device if the button is pressed	1. Press the button and verify the device restarts

Central Monitoring Hub Subsystem

Requirements	Verification
The central unit display should be able to visualize the firefighter data holistically	Have two wearable device sending out simulated information to the central unit to verify it is able to display the firefighters data holistically
Send out a critical alert and change of LED color when abnormal activities occur	Manually input data with different conditions (normal, abnormal, dangerous) to the subsystem and observe whether the alert is turned on or off and whether the data text color changes according to the condition

Power Subsystem

Requirements	Verification
Wearable units should send alerts when the battery is low (below 10%) to the central unit.	Charge the device to 15% and operate the device until the battery drops down to 10% measuring with a multimeter to verify if the alert is sent.
Both the wearable unit and the central unit should last at least 2 hours on a single charge under typical operation conditions (temperatures above 30°C).	Simulate the sensor readings using ADALM2000, record the battery voltage every 5 mins to verify both the wearable unit and central unit has battery life longer than 2 hours.

User Interface Subsystem

Requirements	Verification
Custom-designed graphical user interface (GUI) for the 3.5" TFT touch screen	1. Visually inspect GUI layout on the actual 3.5" screen 2. Verify if all the data received are the same from the wearable units by printing out those data in Serial monitor
Real-time data visualization components (graphs, charts, status indicators)	1. Simulate data input for graphs, charts, and status indicators 2. Verify real-time updates of visualizations 3. Test different data scenarios (normal, critical, edge cases) 4. Measure and verify update frequency matches the requirements
Alert management system with visual and auditory cues	1. Trigger various alert conditions 2. Verify visual cues appear correctly on screen 3. Test auditory alerts for proper sound and volume 4. Confirm alert prioritization works as designed 5. Test alert acknowledgment and dismissal functionality

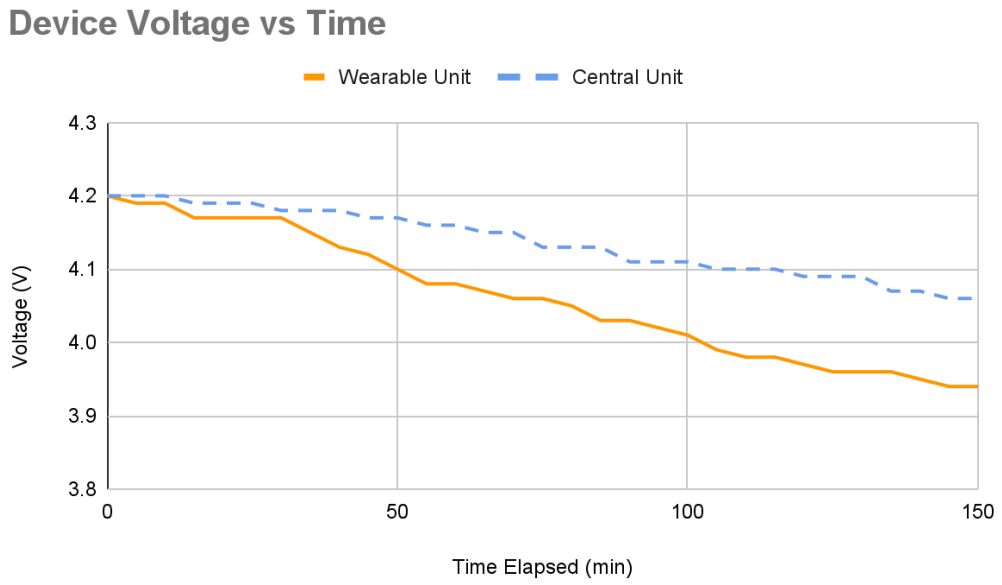
User input handling for system configuration and data queries	1. Test all system configuration options 2. Verify data query functionality with various input parameters 3. Confirm changes are applied and persist after system restart 4. Test edge cases and invalid inputs for proper error handling

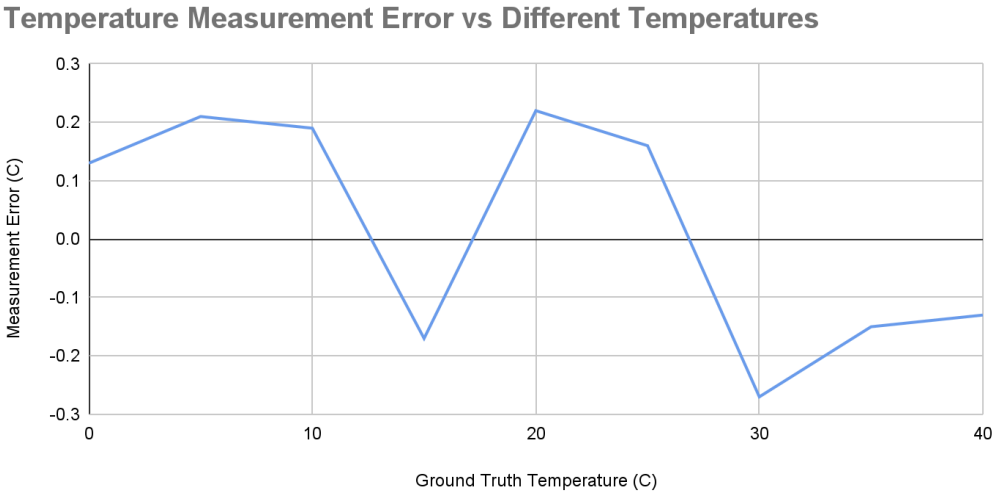
Mesh Network Subsystem

Requirements	Verification
End-to-end (including hops) data transmission time from any firefighter to the central unit shall not exceed 15 seconds, even when relaying through multiple nodes. Communication range of at least 600m in open areas and 250 meters in urban environments.	Calculate the differences between the wearable unit packet sent time using gps time vs the central unit received time to verify the communication time is within 15 seconds.
The devices should be able to create its mesh network so even if a wearable is not directly in range to the central unit it can hop between the other wearable that's in range to connect to the central unit	1. Set up a test environment with multiple wearable units and obstacles to force multi-hop routing. 2. Gradually move units out of direct range of the central hub. 3. Verify data from out-of-range units successfully reaches the central hub via other units. 4. Use network visualization tools to confirm the mesh topology. 5. Simulate node failures to test self-healing capabilities. 6. Measure and compare latency for direct vs multi-hop communications.

Results and Demonstration

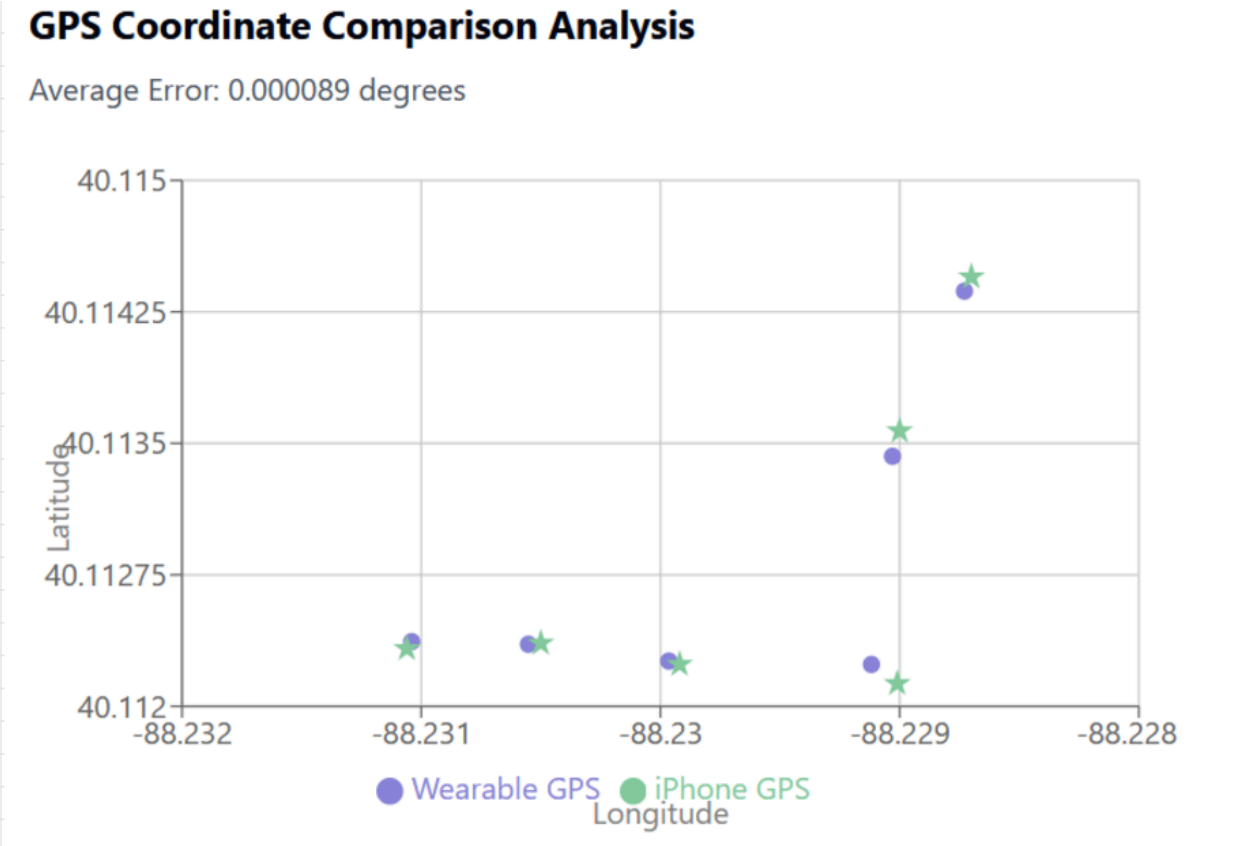
Live Demo Available Requirements
Central Monitoring Hub Subsystem
Power Subsystem (not including 2 hours power capacity)
User Interface Subsystem
Mesh Network (not including ranges)
Wearable Unit Alert/Sensor Subsystem (Excluding GPS)

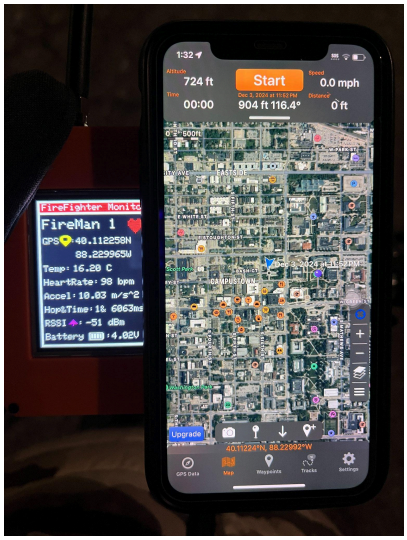


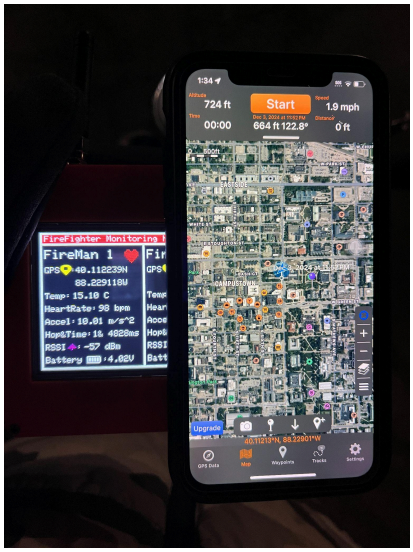


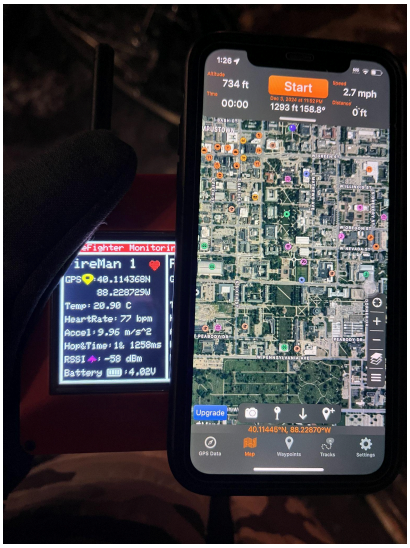
GPS Coordinate Error

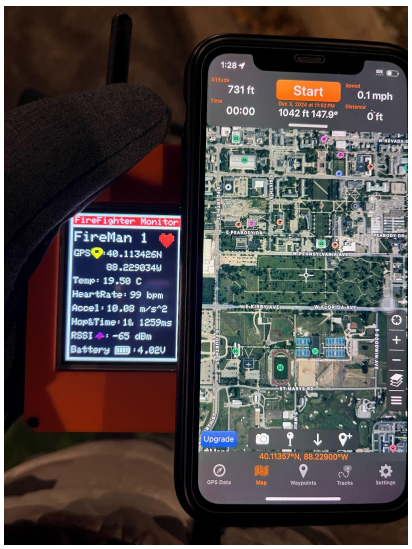
Trial	Wearable Lat	Wearable Lon	iPhone Lat	iPhone Lon	Error (meters)
1	40.114368	-88.228729	40.11445	-88.2287	9.4
2	40.113426	-88.22903	40.11357	-88.229	16.2
3	40.112354	-88.230552	40.11236	-88.2305	4.5
4	40.112369	-88.23104	40.11233	-88.23106	4.7
5	40.112258	-88.229965	40.11224	-88.22992	4.3
6	40.112239	-88.229118	40.11213	-88.22901	15.2
				Average Error	9.05

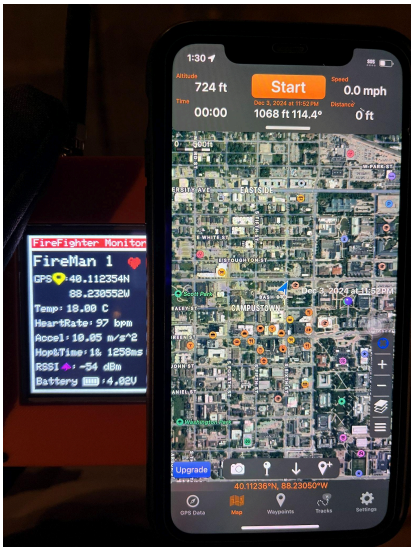


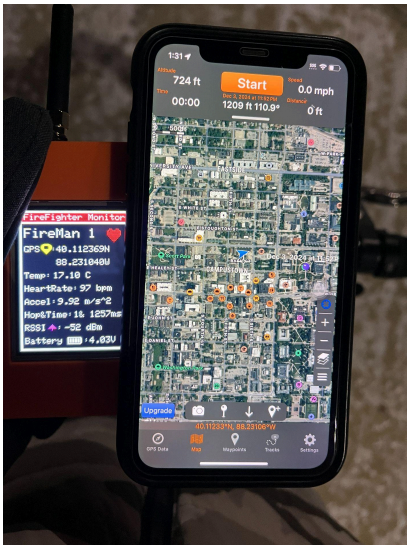

1:32
724 ft
Start
0.0 mph
00:00
904 ft 116.4°
0 ft
FireMan 1
GPS 40.112258N
88.229965W
Temp: 16.20 C
HeartRate: 98 bpm
Accel: 10.03 m/s^2
Hop&Time: 1& 6063ms
RSSI: -51 dBm
Battery: 4.02V
Upgrade
40.11224°N, 88.22992°W
GPS Data
Map
Waypoints
Tracks
Settings


1:34
724 ft
Start
1.9 mph
00:00
664 ft 122.8°
0 ft
FireMan 1
GPS 40.112239N
88.229118W
Temp: 15.10 C
HeartRate: 98 bpm
Accel: 10.01 m/s^2
Hop&Time: 1& 4028ms
RSSI: -57 dBm
Battery: 4.02V
Upgrade
40.11213°N, 88.22901°W
GPS Data
Map
Waypoints
Tracks
Settings


1:28
734 ft
Start
2.7 mph
00:00
1293 ft 158.8°
0 ft
FireMan 1
GPS 40.114368N
88.228728W
Temp: 20.90 C
HeartRate: 77 bpm
Accel: 9.96 m/s^2
Hop&Time: 1& 1258ms
RSSI: -58 dBm
Battery: 4.02V
Upgrade
40.11440°N, 88.22870°W
GPS Data
Map
Waypoints
Tracks
Settings

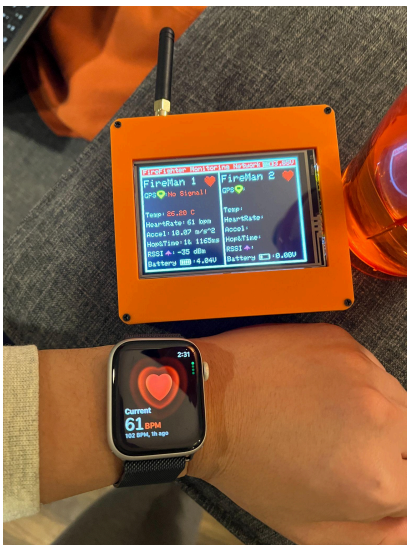

1:28
731 ft
Start
0.1 mph
00:00
1042 ft 147.9°
0 ft
FireMan 1
GPS 40.113426N
88.229834W
Temp: 19.50 C
HeartRate: 99 bpm
Accel: 10.08 m/s^2
Hop&Time: 1& 1259ms
RSSI: -65 dBm
Battery: 4.02V
Upgrade
40.11357°N, 88.22900°W
GPS Data
Map
Waypoints
Tracks
Settings


1:30
724 ft
Start
0.0 mph
00:00
1068 ft 114.4°
0 ft
FireMan 1
GPS 40.112354N
88.230552W
Temp: 18.00 C
HeartRate: 97 bpm
Accel: 10.05 m/s^2
Hop&Time: 1& 1258ms
RSSI: -54 dBm
Battery: 4.02V
Upgrade
40.11236°N, 88.23050°W
GPS Data
Map
Waypoints
Tracks
Settings


1:31
724 ft
Start
0.0 mph
00:00
1209 ft 110.9°
0 ft
FireMan 1
GPS 40.112369N
88.231040W
Temp: 17.10 C
HeartRate: 97 bpm
Accel: 9.92 m/s^2
Hop&Time: 1& 1257ms
RSSI: -52 dBm
Battery: 4.03V
Upgrade
40.11233°N, 88.23106°W
GPS Data
Map
Waypoints
Tracks
Settings

Heart rate beats per min error

Trial	Wearable HR (bpm)	Apple Watch HR (bpm)	Error (bpm)
1	61	61	0
2	57	54	3
3	80	76	4
4	86	89	3
5	99	102	3
6	107	109	2
		Average Error	2.5



Demo Procedure

1. Team Introduction - Individual
2. Background and Problem - Kevin
3. High Level Requirement - Steven
4. Block Diagram - PPT
5. Powerpoint Demonstration of R&V of non-Live demo
6. Lora Range + Battery Life - Kevin
7. GPS Accuracy + Heartbeat Accuracy - Bryan
8. Temperature - Steven
9. Battery Low Power Test
10. Transition to Live Demo - Steven
11. Live Demo
12. Transmission of Sensor Data
13. Heart Rate and No Motion Accuracy
14. Heart Rate Alert (For the purpose of demonstration, we decreased the threshold to 100 BPM sustained for 15 seconds rather than 150 BPM for 30 seconds)
15. Movement Threshold (Les than 0.5 m/s^2 from previous state, susatined for 60 seconds)
16. Surrounding Temperature > 26 Celcius for > 30 seconds (rather than > 40 celcius for 180 seconds)
17. Mesh Network Demonstration
18. Explanation of Mesh Network Approach - Kevin
19. Explanation of Wearable Unit Alert Code - Steven
20. Some Schematic Explanation - Bryan