WIFI - Tomography using Android devices

CS6650 : Smart Sensing for Internet of Things

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Contents

1 | Introduction

WiFi tomography (WiFiT) is a non-invasive imaging technique that uses WiFi signals to create a map of physical space. This technique is based on the fact that WiFi signals are affected by the objects they encounter in their path. WiFiT may be useful in emergencies, rescue operations, and security breaches since the objects imaged need not carry an electronic device.

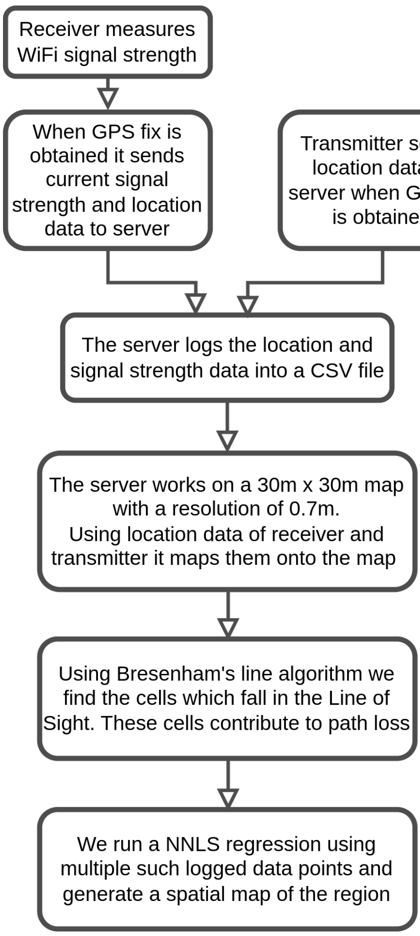
2 | Objectives

We aim to generate a spatial map using a WiFi receiver and transmitter, which send their location and signal strength to a remote server.

3 | Methodology

We use the following flowchart to describe a step-by-step methodology on how our setup works to generate a 2D map of the area.

- WiFi signals pass through most obstacles; they only get attenuated
- It can be performed with very minimal setup; we only require to move around with a sender and receiver and capture data.
- Traditional tomography techniques often require time-consuming data acquisition and processing. On the other hand, WiFi tomography can produce real-time images of a subject.
- WiFi tomography uses low-power radio waves that are not harmful to humans, making it a safe imaging technique.



4 | Procedure

This section outlines a comprehensive procedure for capturing 2D spatial mapping images using two Android devices connected over a wifi network. The procedure involves taking samples in the form of (gpsTransmitter, timestampTransmitter) and (gpsReceiver, timestampReceiver, RSSIValue) to create a detailed map of a physical obstruction as depicted in Figure 4.2.
To capture these samples, we connected the two devices over a WiFi network and moved them in a circular motion to collect GPS coordinates for different locations. GPS values were transmitted to the server automatically when a fix was obtained, ensuring accurate and reliable data collection. Additionally, as these devices were connected over a WiFi network, RSSI values were collected to measure path loss values, which were used to determine the spatial mapping of the physical obstruction.
The transmitter and receiver then send the collected coordinates to a remote server, logging them into a CSV file. The server used the path loss equation and regression to generate spatial mapping results as an image.
This procedure offers a convenient and cost-effective solution for capturing spatial mapping data, making it accessible to a wider range of users and facilitating further research and analysis. Overall, this procedure provides valuable insights into the spatial characteristics of physical obstructions, which can be used for various wireless communication and networking applications.

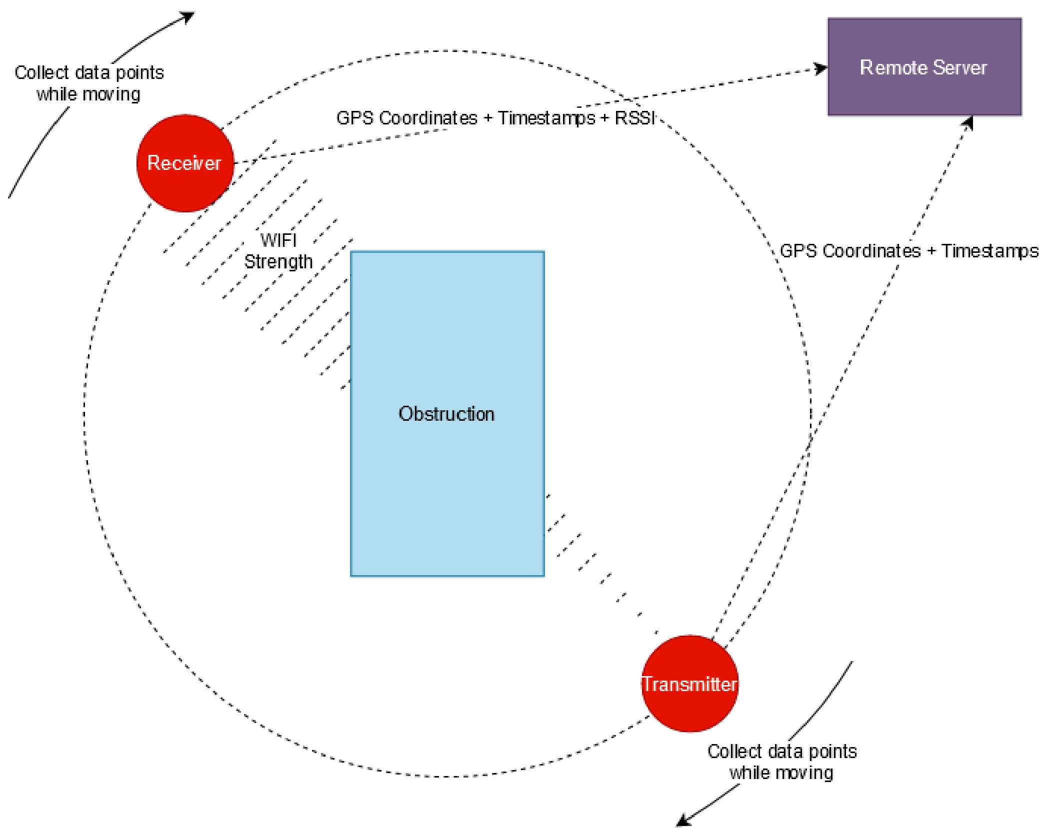


Figure 4.1: Procedure followed to take samples using wifi enabled Android devices

Two strategies were employed to map and compute the results to address the variance in the number of GPS coordinate updates received from two Android devices. These strategies aimed to handle the differences in the amount of data points collected from the devices.

- 1-1 Direct Mapping :
  - This strategy involves establishing a one-to-one mapping relationship between the GPS coordinates received from Device A and B. For example, the 4th entry received from Device A is mapped to the 4th entry received from Device B. This approach ensures the GPS coordinates are synchronized based on their sequential order. Considering GPS coordinates collected sequentially, it is reasonable to assume they are associated with similar or related locations.
  - To maintain a complete mapping, any timestamps that do not have corresponding suitable values in both devices are discarded. This step ensures that only synchronized data points are used for further computations and mapping. By utilizing a reduced set of synchronized data points, the assumption helps to ensure that only the most relevant and reliable data points are used for mapping and computation. This leads to improved accuracy and consistency in the results.
  - By discarding timestamps with no suitable values, the assumption reduces the influence of potentially noisy or inconsistent data points, which may arise due to variations in data collection or device-specific factors. Focusing on synchronized data points minimizes the impact of such discrepancies and enhances the reliability of the mapping process.
- Nearest Timestamp Matching :
  - Temporal proximity implies spatial proximity: The assumption is that GPS coordinates collected at similar timestamps are associated with similar or related locations. Nearest timestamp mapping can address temporal discrepancies or variations in data rates between the two devices, which may be problematic in a 1-1 sequential mapping approach.
  - Tuples with the closest timestamps are mapped to each other in an m-n style matching. This ensures that each data point is paired with the closest corresponding point from the other device. The nearest timestamp mapping strategy allows more data points to be used for computation than a 1-1 sequential mapping approach. This increases the amount of available data for analysis or modeling tasks.
  - However, GPS accuracy can vary across devices, resulting in discrepancies in the mapped results. The assumption of spatial proximity based on temporal proximity may not hold if one device has significantly better or worse GPS accuracy.

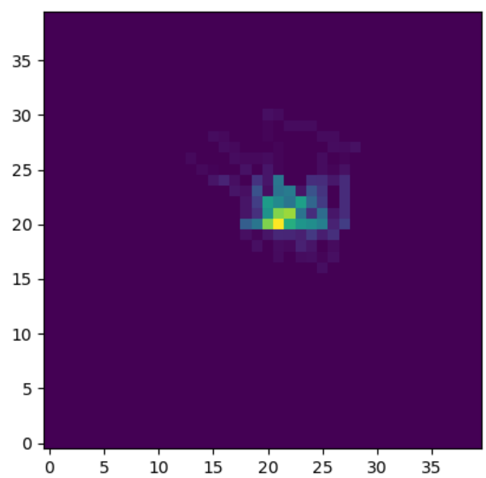


Figure 4.2: Obstacle Map generated by a rectangular obstacle (Grass Roller). Link to video

5 | Result and Limitations

1. Network Latency
   [a] If a far away remote server is used there will be significant network latency
   [b] Computing the regression problem is not feasible on local devices due to the massive memory requirement
2. Location Tracking.
   [a] Receiving a GPS fix can take quite some time, this limits the number of logs we can send
   [b] Accuracy of GPS on modern smartphones is around of range of 1 meter, this is acceptable but not ideal
3. Synchronisation
   [a] Currently we use smartphones as transmitters and receivers, they have their clocks synchronized by Network Time Protocol (NTP).
   [b] We need to perform synchronization if we use simple micro-controllers instead.

6 | Future Research Scope

Currently it often takes quite some time to gather enough data points, especially in closed spaces. This is not ideal given that a major use case for this research is mapping closed spaces which are inaccessible. Also, often an incorrect GPS fix can cause an erroneous map which makes it difficult for the user to identify if its simply low attenuation due to a transparent material or an singular incorrect fix. We can look into better methods of location tracking.

7 | References

1. Wireless tomography, Part I: A novel approach to remote sensing
2. Radio Tomographic Imaging with Wireless Networks
3. Bresenham's line algorithm
4. Non-negative least squares
5. GitHub repository link for the project.