Visualizing RF Signal Strength in Mobile Ad Hoc Networks using CloudRF API and Known Path Loss Models

Jeffrey Lee, Isaac Blankenau & Dr. Ahmet Soylemezoglu
Robotics for Engineer Operations Team, US Army Corps of Engineers Construction Research Engineering Laboratory

Abstract

A Mobile Ad hoc Network (MANET) is a spontaneous network consisting of wireless nodes which are mobile and self-configuring. Devices in MANET can move freely in any direction independently and change its link frequently to other devices that are within range. Due to its dynamic nature, accurate mapping of radio frequency (RF) signal strength is crucial for optimizing network performance. While path loss models, ray tracing, and radio propagation software are widely employed for predicting RF signal strength, a significant knowledge gap exists in assessing the accuracy of these tools in the context of MANET.

This research project consists of two parts. The first part evaluates the performance of three popular path loss models: the Friis Transmission Equation, Okumura, and Okumura-Hata. Additionally, CloudRF, a cloud-based RF signal strength platform, is evaluated alongside these traditional models using the ITU-R P.1546 model configuration. The evaluation uses measured data from two Persistent Systems MPU5 military radios in two different environments, suburban and urban Champaign, IL, with radios in line-of-sight at distances up to 1000 feet. The second part of the project involves building a dynamic mapping platform that utilizes a WebSocket connection to acquire GPS data from the radios, makes requests to CloudRF API, and saves the calculations in a KML file, which is then uploaded to Google Earth for visualization every second. This visualization enables us to observe the dynamic changes in signal strength as nodes move, which gives us an understanding of their behavior and performance.

Motivation

- Our team uses Persistent Systems MPU5 radios on our autonomous platforms to enable ROS2 (Robotic Operating System) communications to each other
- These autonomous units are deployed in unstructured environments where radio communications are necessary
- Due to the limited range of the radios, it is essential to know the locations and signal strengths of the autonomous platforms to maintain control over them

Persistent Systems ANT-2003 Antenna Design

CloudRF requires users to set basic parameters to calculate radio signals based on the inputs. One of the most important parameters is specifying the radiation pattern for the antenna. Using Antenna Pattern Editor, I was able to create the radiation pattern of the vertical and horizontal polarizations.

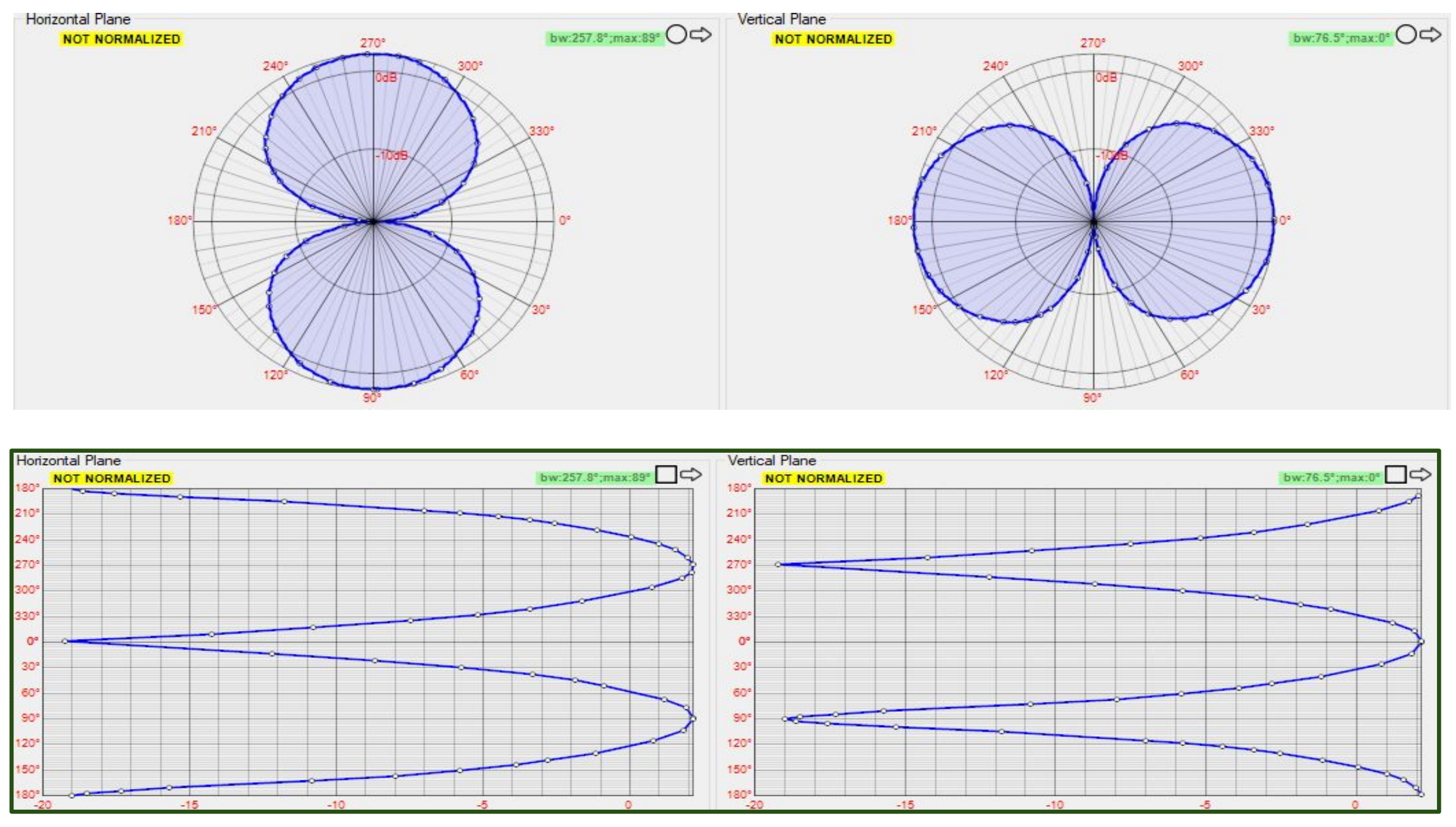

Figure 1: Radiation pattern of ANT-2003 omnidirectional antenna in reference to isotropic radiation pattern of 0dB.

Horizontal Plane (left graph): Maximum gain is 2.15dBi at 90° and 270° with a horizontal beamwidth of 257.8°

Vertical Plane (right graph): Maximum gain is 2.15dBi at 0° and 180° with a vertical beamwidth of 76.5°

Approaches and Results

Friis Transmission equation is a mathematical model that calculates power loss of radio waves in free space. All path loss models are based off of the Friis Transmission.

$$p_r = p_t + g_t + g_r + 20\log\left(\frac{\lambda}{4\pi d}\right)$$

Pr is the received power, Pt is the transmitted power, Gt is the gain of the transmitter antenna, Gr is the gain of the receiver antenna. Also a constant is applied due to signal loss as distance increases which depicted as a log function.

- Acquired real-time data from the MPU5 radios at two different site locations in Champaign: USACE CERL and the CU Astronomical Society Observatory. USACE CERL is based on a suburban environment while the CU Observatory is based on a rural environment
- MPU5 radios' configuration was set to 2222 MHz frequency, 20 MHz bandwidth, 34.77 dBm transmit power, and -100 dBm noise floor.
- The distance between the radios were set in increments of 100 feet, up to 1000 feet, and the SNR ratio was logged and converted to receiver power.
- The same calculations were made using the path loss models and CloudRF, and plotted on a line graph to see which model is closest to the actual obtained values.

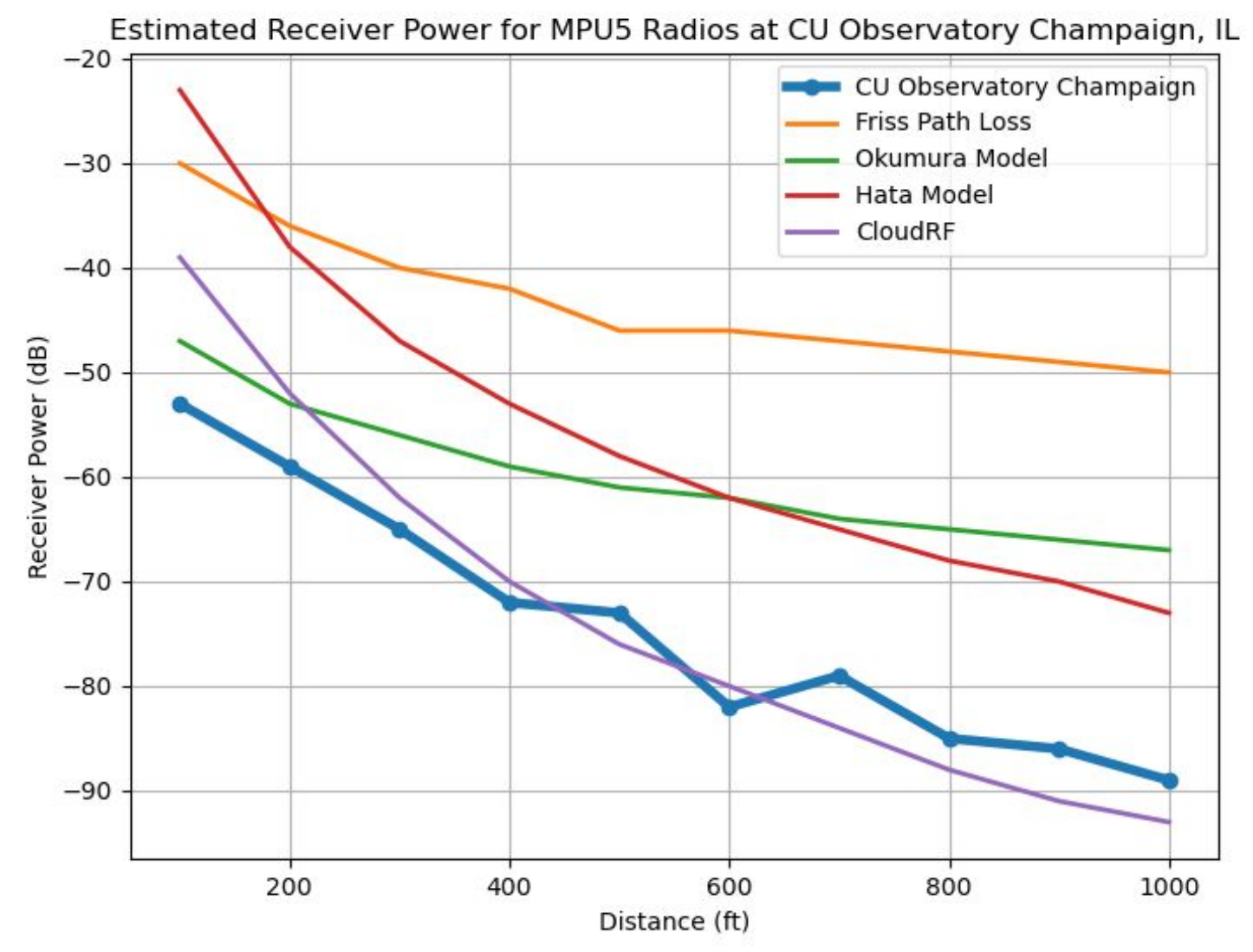

Figure 2: Receiver Power (dB) vs Distance for MPU5 Radios at CERL Champaign, IL

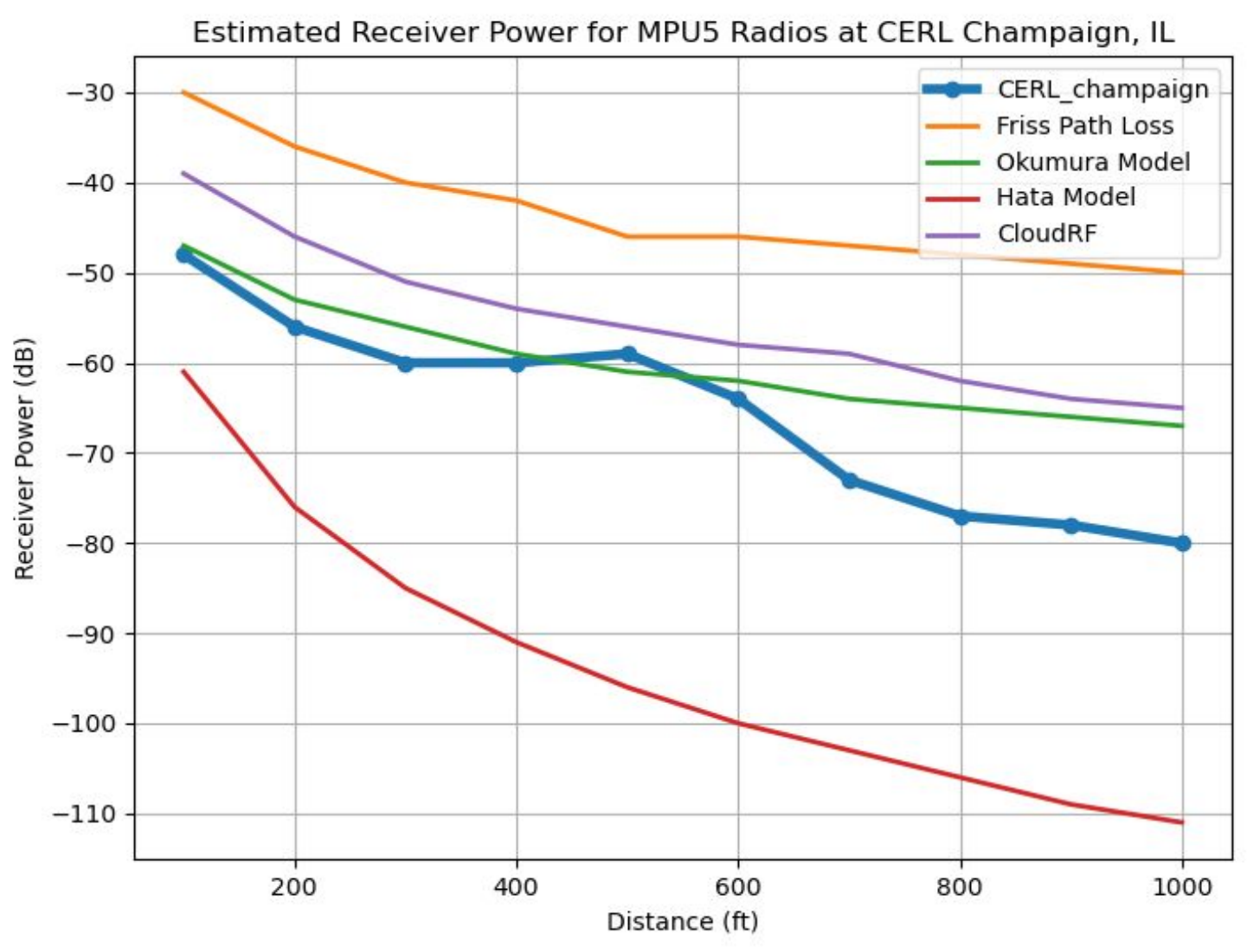

Figure 3: Receiver Power (dB) vs Distance for MPU5 Radios at CU Observatory Champaign, IL

Visualizing Networks Using CloudRF API

Methodology:
A JSON-formatted request is generated using a predefined template and upon receiving a response, the data is parsed to extract the required GPS coordinates.

```
websocket.send(json.dumps({
        'msgtype': "req",
        'protocol_version': "1.4.0",
        "command": "get",
        'username': 'factory',
        'password': 'password',
            "variables": {
                "position_status_json": {
                },
            }
        }))
```

Initialize WebSocket Connection

Get Current Radio Location

Get Neighboring Radio Locations

Make API Request to CloudRF

Process API Response

Generate KML File

Radio Map Teaser

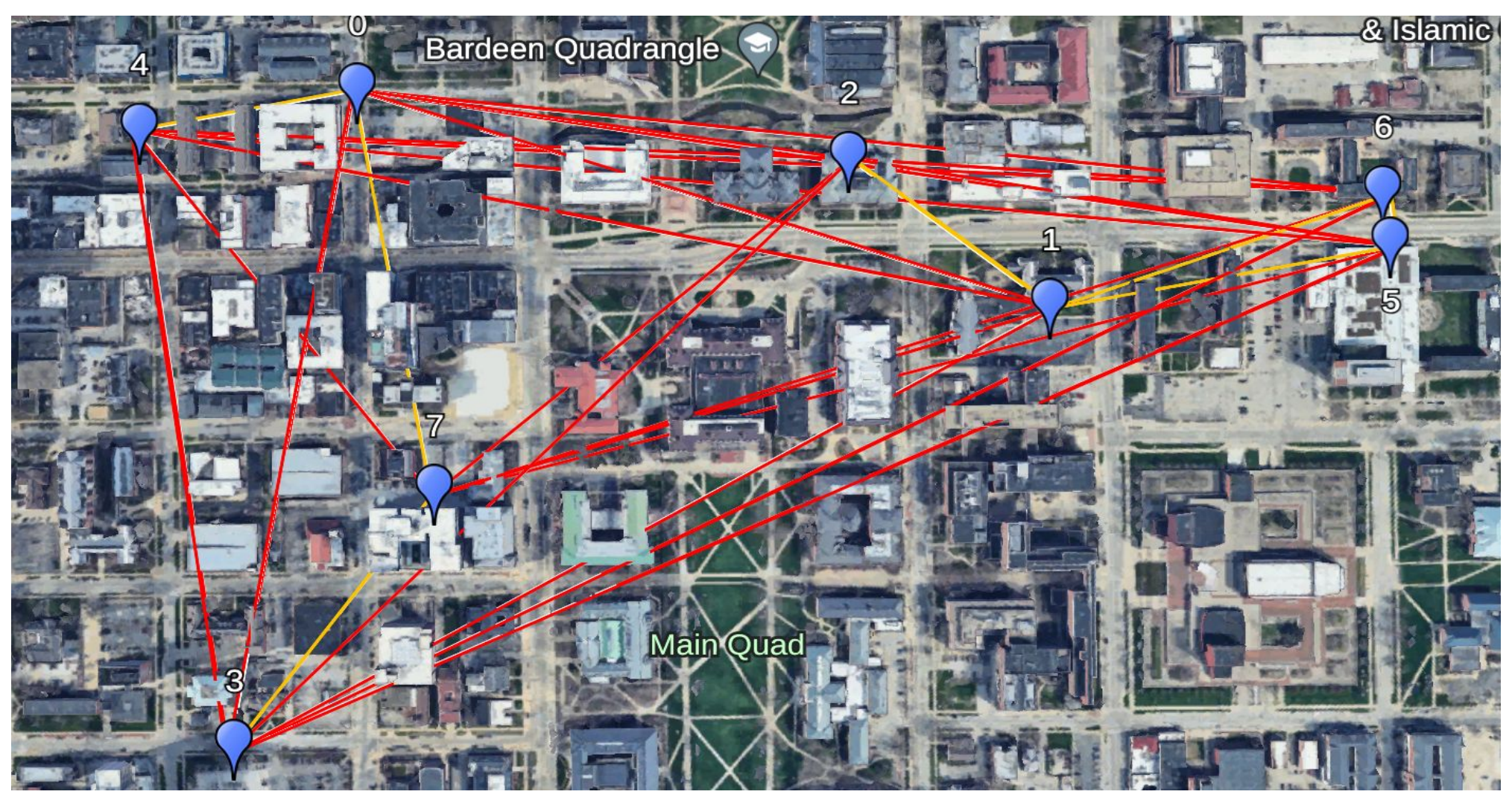

Figure 4: 8 random locations around the Illini Union, where the radio signal strength is mapped: red lines indicating below -80 dBm, yellow lines indicating below -60 dBm, green lines indicating above -60dBm

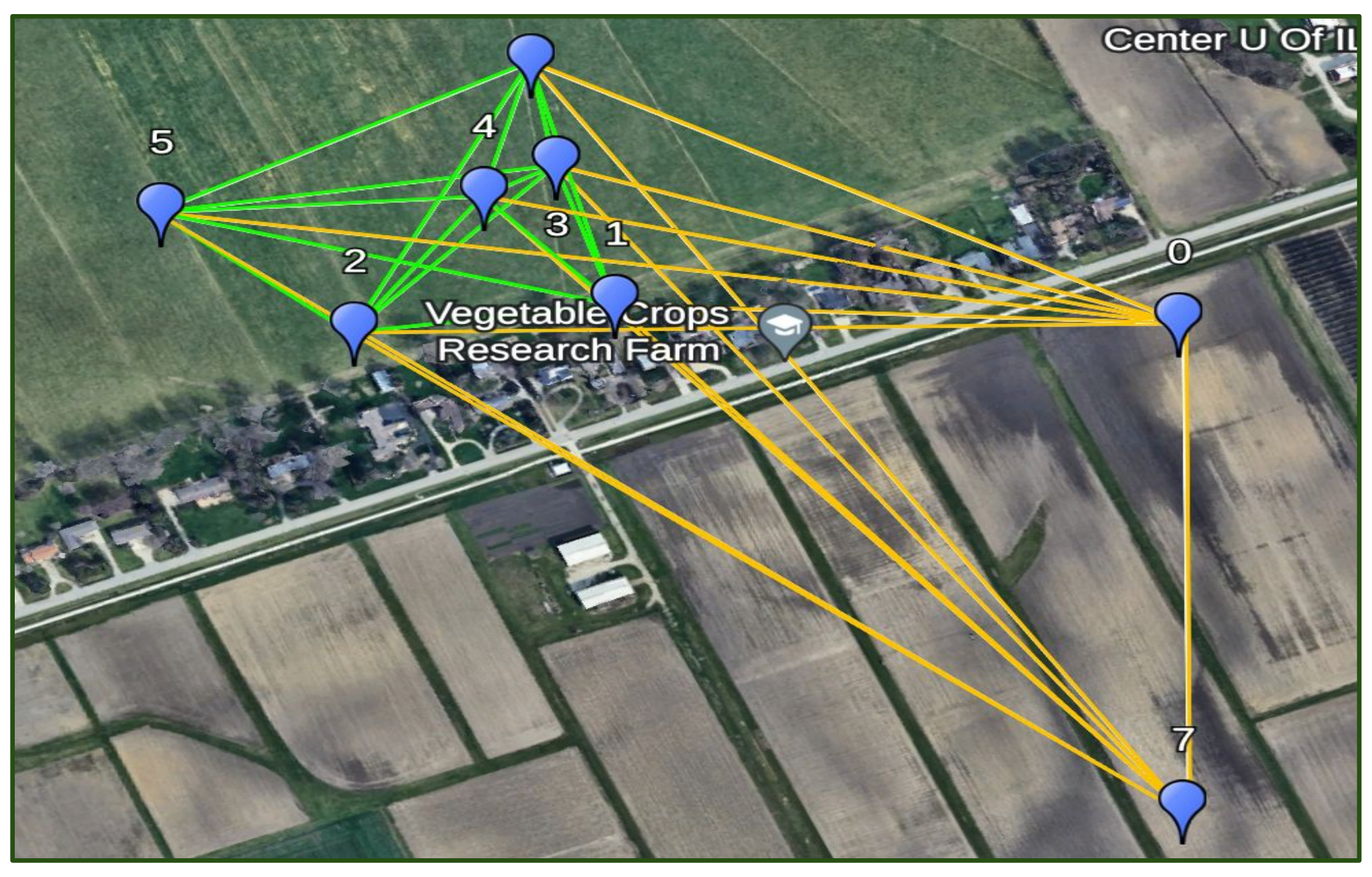

Figure 5: 8 random locations around the Vegetable Crops Research Farm, revealing a notable improvement in signal quality relative to the Illini Union.

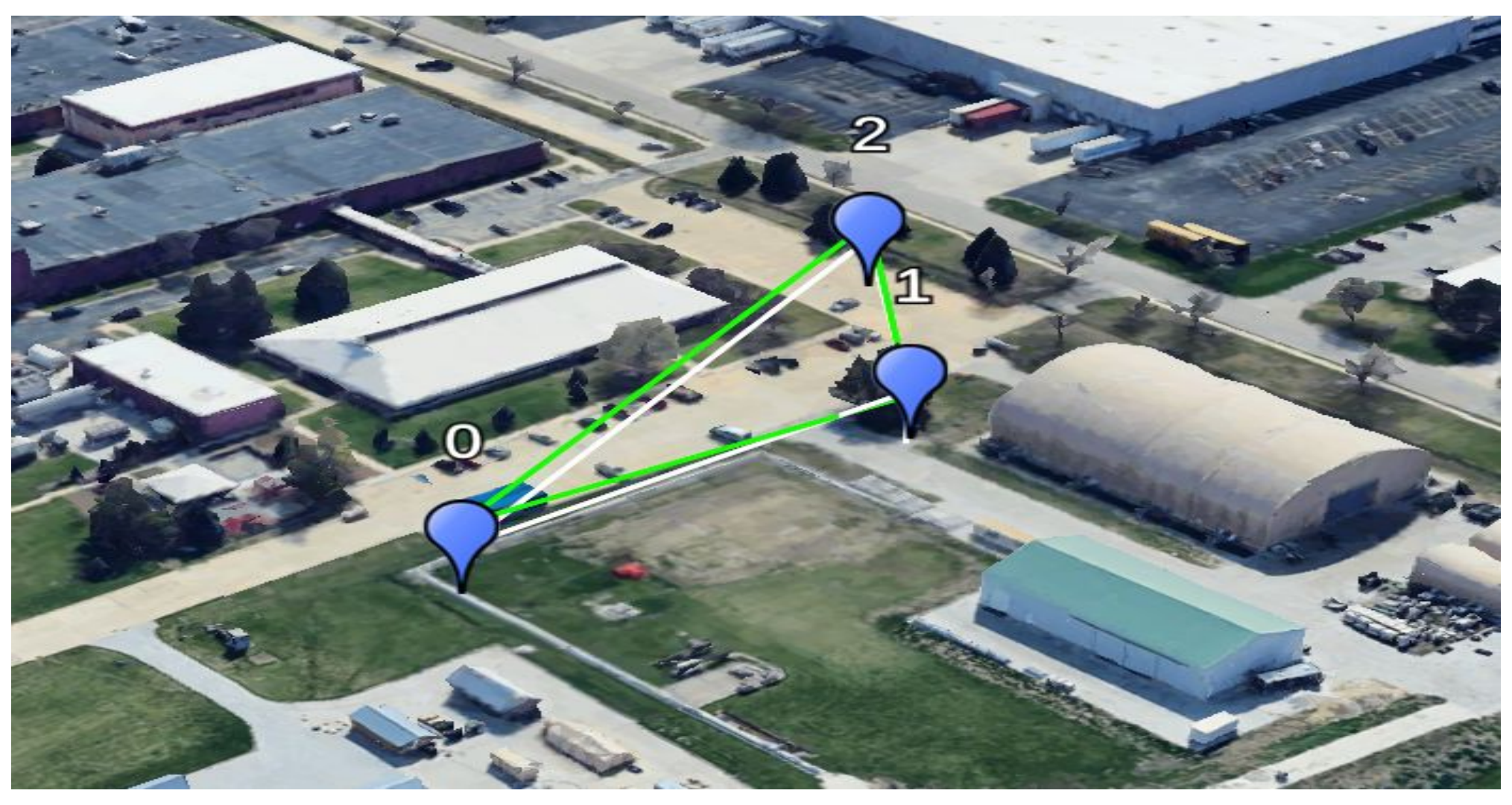

Figure 6: Persistent Systems radios mapped in real-time outside of USACE CERL

Future Work

- Continue exploring known path-loss models and develop a optimized model that reflects our terrain and environment
- Revise my script to randomly set a new route for each radio node, simulating movement and allowing real-time visualization of connections being reassigned
- Implement this script in a ROS2 package using publisher/subscriber techniques to enable our autonomous platforms to stay within range of each other

References

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FOR FURTHER INFORMATION

POINT OF CONTACT:
Jeffrey Lee
jlee414@stu.parkland.edu