5G Network Performance Testing – Team Red (Sky Seer)

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Project Summary — As commercial implementations of aerial drone fleets become more prevalent, there is an increasing need for beyond line of sight (LOS), autonomous operations. These would rely on connections to mobile communications networks such as 5G. Currently, there is minimal understanding of whether 5G networks can support drone operations at altitudes of up to 400 feet above ground level. To learn more about the ability to operate drone fleets effectively, this project will collect network connectivity data and model it at various altitudes and conditions. We propose the installation of a 5G connected hardware apparatus on a drone, furnished with sensors and capable of running network speed tests. Once the data are collected, they will be stored in a cloud database and will be accessible for the design and implementation of machine learning models that predict network performance on the ground and in the air.

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1 Need for this Project

Innovation in unmanned aerial vehicle (UAV) technology has introduced the possibility of companies deploying large fleets of drones to accomplish tasks that otherwise would require a significant allocation of labor and material costs [1]. One example is Prime Air, Amazon's drone delivery service that promises to deliver packages less than 5 pounds in less than 30 minutes [2].

However, not every company has the ability to implement its own satellite network, such as Amazon's Project Kuiper [3], and would have to rely on existing networks (i.e. AT&T or Verizon's 5G networks) to control their UAVs beyond LOS. Currently, there is not sufficient understanding about the performance of 5G networks in the air due to them largely being designed for use at ground level because the vast majority of internet-enabled mobile devices operate on or near the ground.

Companies that wish to deploy UAVs to accomplish tasks remotely need to know how 5G networks like AT&T's perform in the air to determine the feasibility of relying on these networks to operate their drones safely and successfully. The cost of a drone losing connectivity with its operator during a task could be catastrophic. In addition to damage to the drone itself or its payload, a drone losing contact with its operator could result in damage to public and private property, with the potential for injury to people on the ground.

Additionally, companies need to know if 5G network speeds are capable of supporting remote drone operations. UAVs need to be able to communicate with their operators with minimal latency, as operators may need to execute precise maneuvers to carry out tasks. Network performance must be robust enough to maintain communication between drone and operator, and to ensure that an operator can still exercise full control of their drone(s).

2 Problem Statement and Deliverables

Given that current telecommunications networks like 5G are built and tested with the goal of serving users near ground level most effectively, it is necessary to obtain a better understanding of how these same networks perform at altitude. Without a thorough understanding of network performance as it pertains to drone operations, companies operating drone fleets beyond LOS on current networks pose risks ranging from economic and property losses to the endangerment of people's safety.

This project aims to develop a better understanding of 5G network performance in the air, which will in turn provide a better understanding of the feasibility of operating fleets of drones beyond LOS. This will be accomplished by developing machine learning models that predict what the network speed in the air would be given ground network speeds as well as what the network speed on the ground would be given air network speeds. The air network speeds will be limited to altitudes up to 400 feet above the ground because that is the Federal Aviation Administration's limit on small UAVs. Additionally, the models would account for various conditions and variables that come into play with network performance, such as more urban versus more rural geographies, time of day, and day of the week.

In order to develop machine learning models, a training dataset is required. Since there is not an already existing relevant dataset, this project also implicitly requires the creation of one. While it is not an explicit deliverable of this project, it will therefore be necessary to create data collection hardware. This will consist of a quadcopter type drone with attached peripherals to conduct the network performance and altitude measurements.

The findings of this project will enable network providers such as AT&T to take any necessary corrective or preparatory action to mitigate the potential risks associated with companies operating drone fleets on their 5G networks.

3 Visualization

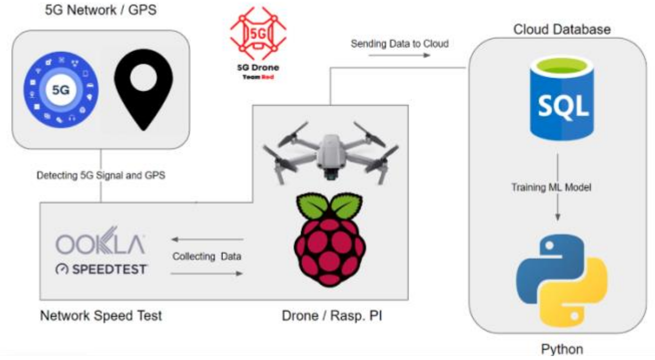

Fig. 1. This is a diagram of the overall system. The drone platform will connect to a 5G network and will be able to detect altitude to gather data. To accomplish this, a Raspberry Pi with additional modules will be attached to the drone. Network performance data will be gathered by the Raspberry Pi through a network speed test. Altitude data will be gathered by the Raspberry Pi through attached sensors. All of the data will be stored in a cloud database. The collected data can then be accessed through the database to train the machine learning models for the project.

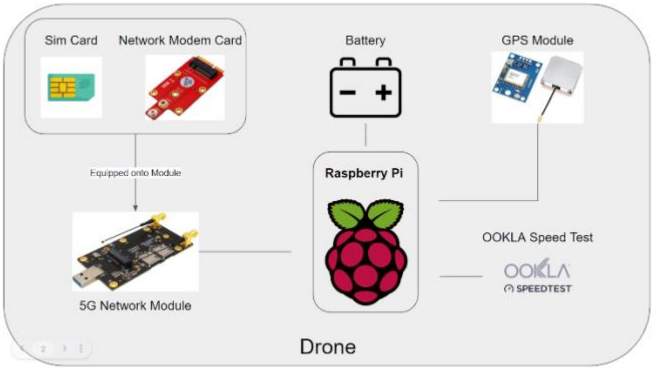

Fig. 2. This is a diagram of the data collection apparatus. A Raspberry Pi with additional modules will be attached to the drone to enable the collection of network speed and altitude data. First, the SIM card and the modem card are inserted into the 5G network module, which is then attached to the Raspberry Pi via USB 3.0. This allows the Raspberry Pi to detect and connect to the 5G network and run the network speed test. Second, a GPS module is connected to the Raspberry Pi to measure altitude and position. Lastly, the Raspberry Pi is powered by a portable battery.

4 Competing Technologies

There are multiple companies that have been involved in 5G network performance testing. Their initiatives and products can be divided into two categories in relation to this project.

The first category of competing technologies is similar to our project in that they use 5G network performance testing data, but they use the data in ways different from this project.

- Qualcomm [4]
  - Qualcomm Snapdragon features a comprehensive modem-to-antenna system solution for 5G multimode devices.
  - The product is designed to intelligently work and to consistently deliver high cellular speeds, superior coverage, and power efficiency in sleek form factors.
  - The testing data is categorized into different environments such as urban or suburban but is not specified with altitudes like it would be for this project.
  - The product does not conduct predictions of network performance with machine learning models.

- OpenSignal [5]
  - OpenSignal is an application that measures everyday experience received on a mobile network.
  - The application does not provide predictions or best-case scenarios. Instead, it focuses on the real time true network speed.
  - It is quite similar to Ookla, which is what will be used in this project, but a key difference is that OpenSignal emphasizes video experience. Ookla has video tests, but this project will focus on the exact bps of networks.

The second category of competing technologies involves drone-based network testing. These companies mainly focused on drone control and navigation with network connectivity.

- Vodafone and Ericsson [6]
  - Vodafone and Ericsson launched autonomous drones flying under mobile network connectivity.
  - Using network coverage and intelligence, they are working to enable safe, beyond LOS flights for autonomous drones, similar to this project.
  - One of the products they are producing are network coverage maps for UAVs, which is also similar to the modeling aspect of this project.
  - Their testing was conducted in Europe while this project will use networks in the US.
  - Autonomous flight technology, like that used by Vodafone and Ericsson, can possibly be implemented in our project to assist with the data collection process.

- Ericsson [7]
  - Ericsson Connected Drone Testing enables network operators to move forward with a solution for drone testing on LTE networks so that network operators can test if their LTE systems can support UAVs.
  - Contains the additional aspect of cybersecurity testing with LTE and Wi-Fi enabled drones and field testing with real-time connected drone network performance analytics. Cybersecurity testing is not within the scope of our project.
  - Unlike our project, it focuses on LTE rather than 5G network performance for drones.

5 Engineering Requirements

This section divides the various engineering requirements by their respective components of the overall system.

1. Hardware
   A. The drone must be able to fly up to 400 ft with the attached peripherals.
   B. The drone must be able to fly for about at least 10 min on a full charge.
2. Data Collection
   A. Must be able to measure altitude within 10 ft.
   B. Must be able to measure 5G network speeds in Mb/s (download and upload) to at least 1 decimal place precision.
   C. Must be able to measure GPS coordinates (latitude and longitude) to at least 3 decimal places.
3. Data Storage
   A. Database needs to be able to store at a minimum 20 MB of training data (altitude, GPS position, 5G network speeds).
   B. Data will be importable into Python for machine learning model implementation.
4. Modeling
   A. Machine learning models must predict network

speed in the air based on speed on the ground and also predict speed on the ground based on speed in the air.

B. Models must have at least 80% test accuracy (less than 20% test error).

5. Cost

A. The total cost of all of the components of the project must not exceed $500.

6 Appendix A References

[1] P. Cohn, A. Green, M. Langstaff, and M. Roller. “Commercial drones are here: The future of unmanned aerial systems.” mckinsey.com. https://www.mckinsey.com/industries/travel-logistics-and-infrastructure/our-insights/commercial-drones-are-here-the-future-of-unmanned-aerial-systems (accessed Oct. 17, 2021).

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[3] Amazon. “Amazon receives FCC approval for Project Kuiper satellite constellation.”aboutamazon.com. https://www.aboutamazon.com/news/company-news/amazon-receives-fcc-approval-for-project-kuiper-satellite-constellation (accessed Oct. 17, 2021).

[4] Qualcomm. “Qualcomm Snapdragon Mobile Platforms, Processors, ModemsandChipsets.”qualcomm.com.https://www.qualcomm.com/snapdragon (accessed Oct. 17, 2021).

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[6] Ericsson. “Autonomous drones flying under the mobile network connectivity.”ericsson.com. https://www.ericsson.com/en/cases/2021/long-distant-flights-for-autonomous-drones (accessed Oct. 17, 2021).

[7] Ericsson. “Connected Drone Testing.” ericsson.com. https://www.ericsson.com/en/portfolio/digital-services/transform-business/device-and-network-testing/device-and-application-verification/connected-drone-testing (accessed Oct. 17, 2021).

Email response from client regarding PDRR:

Timothy Geraghty

to me, Jong, Do, Jung, Peter

Sat, Nov 27, 10:10 AM

Hi Ryan -

I acknowledge reading the report and approve you are on the right track with this project.

Thanks,
Tim