Holistic Approach for Multi-Drone Data Collection

Ava Moon, Cody Fellinge, Corey Schanker and Priestly Barigala

Advised by Jonathan Diller and Dr. Qi Han, PeCS@Mines

COLORADO SCHOOL OF MINES

CS@Mines PeCS

INTRODUCTION

In this project, we are building off our previous work on Holistic Path Planning for Multi-Drone Data Collection.

Limitation to our previous work include

- not properly handling connectivity issues
- limited model for wireless communication
- ignoring limited drone energy online

To improve our holistic approach, we have several objectives:

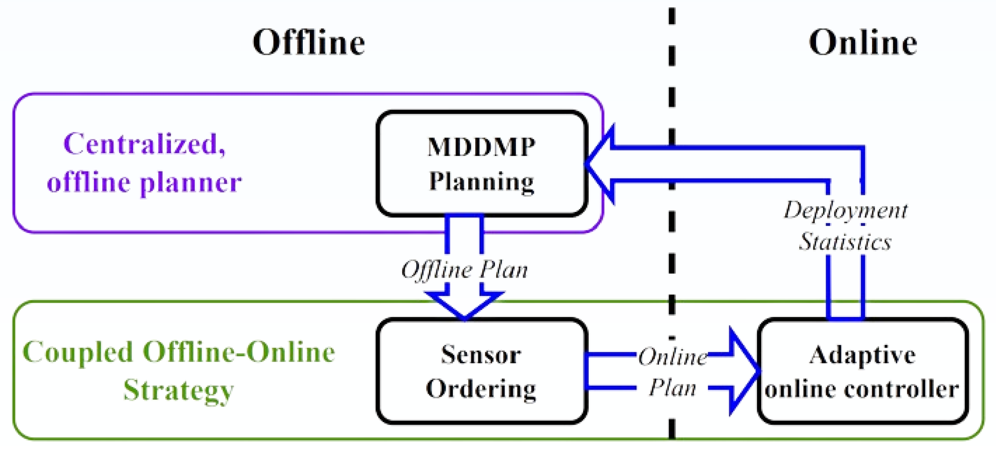
- Develop physical testbed for experiments
- Perform data collection tests to determine limitations on range and amounts of data
- Implement energy model into autopilot
- Perform field tests with testbed and wireless sensors
- Feed data from field test to energy model
- Optimize energy budget in offline vs. online planning

SUMMARY OF PREVIOUS PROGRESS

Drones can be used as data mules to collect data from wireless sensors to mitigate issues found in traditional ground-based networks. However, there are many open challenges to address in this problem that our team has been working on.

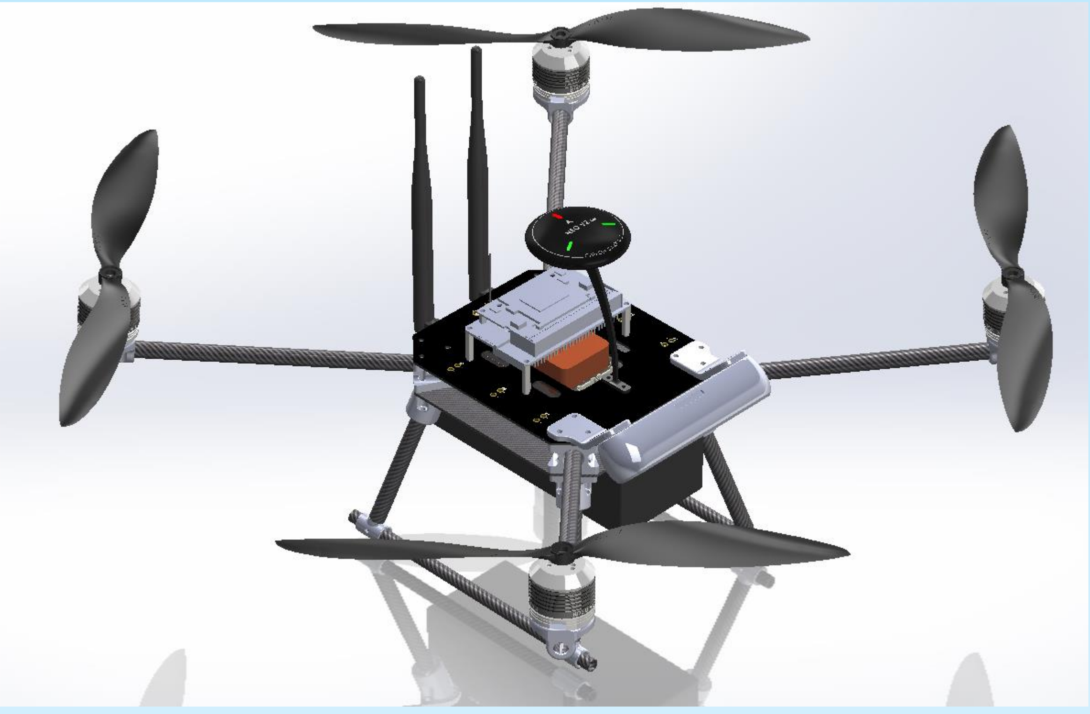
Previously, we have:

- Addressed the challenge of forming a plan to deploy a team of UAVs to collect data from wireless sensors while minimizing data latency
- Proposed holistic solution where we form coupled offline-online strategy
- Offline plan considers energy restraints and turning the problem into a variation of the Vehicle Routing Problem
- Online strategy adapts to the unpredictable nature of wireless transmitters and receivers as needed and accounts for realistic drone energy.
- Developed DroNS-3 – a software framework for integrating the Ardupilot SITL drone simulator and NS-3 networking simulator



DRONE TESTBED IMPROVEMENTS

The project utilized a custom drone tailored to emphasize autonomous mission capabilities. In addition to the project's primary goals, the project seeks to establish an open-source custom drone platform. By doing so, we aim to revolutionize multi-drone research, introducing heightened versatility, robustness, and autonomy, thereby catering to a broad spectrum of applications.



The drone:

- Uses a Raspberry Pi 4 as an onboard computer
- Ensures reliable flight through multiple redundancies in both hardware and software
- Offers flexible options for payloads and companion computers
- Modular design and open-source files for easy customization to suit any research project's needs.

Specification	UAV Performance
Cost Without Companion Computer	$1254
Mass	2270g
Max Payload	1880g
Max Hover Time Without Payload	28 minutes
Max Hover Time With 1000g Payload	18 minutes

DEPLOYING DRONE

The drone platform and our custom autopilot can be deployed in both simulation and in the field.

- Initial testing done using DroNS-3, allowing us to verify data collection missions in a controlled simulation environment
- For field testing, the Raspberry Pi 4 running our custom autopilot and configured for Ad-Hoc communication allows the drone to couple communication and control

ENERGY MODEL

To see the percentage of potential seconds of travel (ρ) the UAV has used at any given point, we have implemented an energy model onto the UAV autopilot.

Let P(v) be the function that maps speed to power, $d_{i,j}$ be the euclidean distance between x_i and x_j, v be speed, B_{rate} and V_{bat} are battery parameters. Assuming a fixed speed during the mission or a speed of 0 while hovering, we can calculate:

- The total amount of time the drone can travel at v_m :

$$s_m = \frac{B_{rate} V_{bat}}{P(vm)}$$

- The total amount of time the drone can hover:

$$s_h = \frac{B_{rate} V_{bat}}{P(vh)}$$

- Flying from x_i to x_j will consume

$$f(i, j) = \frac{d_{i,j}}{v_m} \rho$$

- Hovering for a duration of t seconds will consume

$$\frac{s_m}{s_h} t \rho$$

Implementing this energy model into the object-oriented python code base of the DroNS3 autopilot allows us to better account for the energy constraints of UAVs during missions, leading to more efficient data collection.

CONNECT COMMAND

To implement functionality for connecting to wireless sensors and sending various amounts of data, we created a custom command for the DroNS-3 autopilot. This command:

- Uses subprocesses to call a C script that connects to a server's listening port
- Sends large amounts of data in increments to avoid errors
- Writes information to a file each time it is called, including connection success, time to connect, and distance from the server
- Can be added into any mission plan file

SIMULATION

Both the energy model and Connect command:

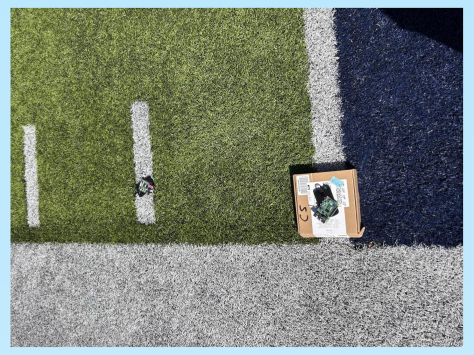
- Were created to work with both physical drone testbeds and Ardupilot SITL drone simulator
- Were tested throughout development with Ardupilot
- Designed and implemented into the DroNS-3 autopilot

Ardupilot SITL Flight Simulation

CONNECTION TESTS

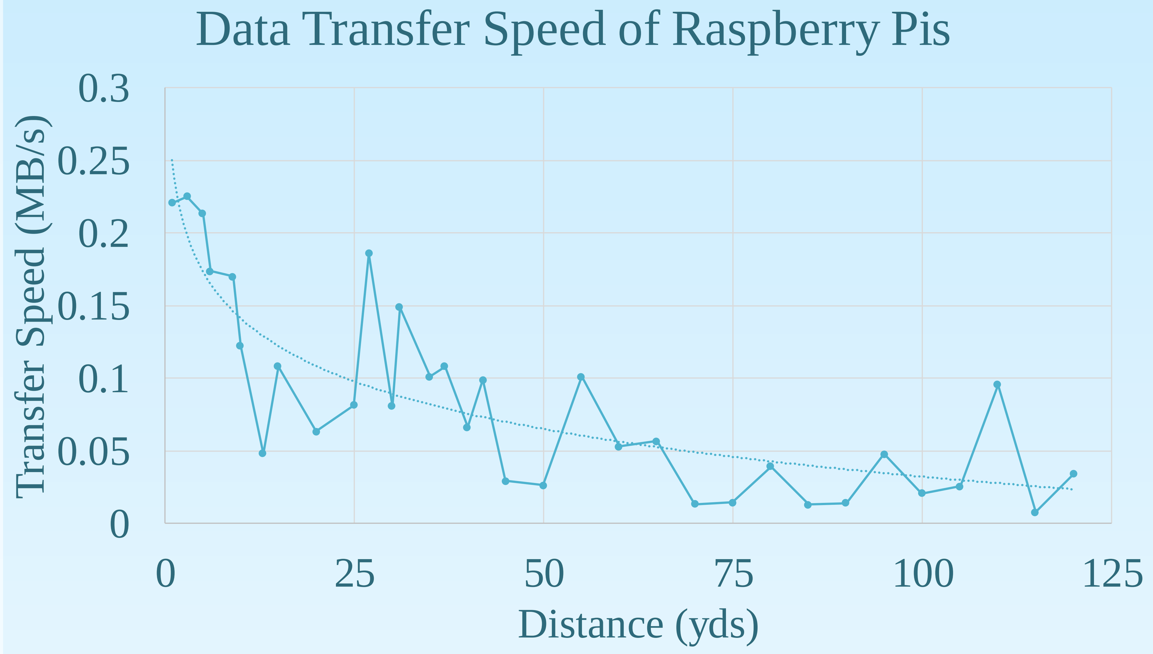
Using the custom Connect command, we performed tests to simulate a drone flying near a series of ground stations and collecting data from the ground station.

- Raspberry Pi 4's transmitted large amounts of randomly-generated text data at ranges from 1 – 120 yards.



FINDINGS

We graph the average transfer speed, in Megabytes per second, vs. various ranges. Several tests were conducted at each range, so we show the average speed at each range.



- Results follow the inverse square law, which governs how signal strength decays over distance.
- Tests performed better when one Pi was suspended about 1.5 meters off the ground, suggesting better performance may be achieved using an actual drone.

ONGOING WORK

- We will continue to implement the networking protocols used in the connection tests and improve their robustness
- Run similar connection test using multiple ground stations and multiple drones
- Integrate connection tests and energy model to work with NS-3
- Plan data collection missions using findings:
  - Use data from connection tests as parameters in the energy model
  - Use energy model to calculate approximately how many potential seconds of travel a mission will use
  - Better budget energy for offline versus online planning to improve upon holistic path planning

ACKNOWLEDGEMENTS

Mines Undergraduate Research Fellowship