Open-Source Prototyping of 5G Wireless Systems for Unmanned Ground and Air Vehicles

Design Document

Team 13

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Executive Summary

Development Standards & Practices Used

- 3rd Generation Partnership Project (3GPP) Release 16 (Rel16)
- IEEE 802 family of standards
- Agile framework with Scrum methodology
- Open-source software utilization
    - Open Air Interface (OAI)
    - New Paparazzi Simulator (NPS)
    - JSBsim Flight Dynamics Model (FDM)

Summary of Requirements

- Integrated simulator should be able to successfully simulate communication among UAVs on a 5G wireless system
- Simulator should be able to consider outside weather conditions and environmental hazards when scheduling UAV routes
- Simulator should be open-source and free to use among the research community

Applicable Courses from Iowa State University Curriculum

- ENGL 314 - Helped in the creation of reports, checking for grammatical errors, and outlining of reports
- SE/COM S 309 - Early project experience helped facilitate working and operating within a team
- COM S 352/CPRE 308 - Understanding of operating systems necessary for implementing drone software and navigating Linux
- CPRE 489 - Computer Networking and Data Communications helped in understanding client server programming, data and routing protocols and most importantly local area networks.

New Skills/Knowledge acquired that was not taught in courses

- 5G implementation knowledge
- Drone development and simulation
- Usage of simulation software and Linux distribution such as Ubuntu

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1 Introduction

1.1 Acknowledgement

We thank Professor Zhang for all the assistance in the guidance of this project, as well as the provision of other sources of information for Drone Simulation, OAI setup, and remote access to computers.

1.2 Problem and Project Statement

Inter-vehicle communication for unmanned aerial and ground vehicles is needed to improve the safety and sensing capabilities for autonomous functionality. Current 4G, LTE network architecture does not meet the latency requirements to ensure reliable inter-vehicle communication. Our group will implement a next generation 5G wireless network simulation and real-time scheduling algorithms to demonstrate reliable transfer of packets between vehicles.

Our project will focus on the implementation of 5G networks for unmanned aerial vehicles, or drones, and real-time scheduling algorithms associated with communication among these vehicles. We will simulate how drones can be improved with 5G, while also staying efficient, safe, and cost-effective. This simulation will have applications in areas such as drone delivery, agricultural surveillance, and search and rescue drones.

1.3 Operational Environment

Our simulation should be able to take outside weather conditions into consideration when planning vehicle routes. We assume that drones will be able to handle and plan accordingly to common weather hazards, such as wind, rain, and snow. Drones will also need to be aware of other hazards in their environment such as large buildings or structures and other drones in their route.

1.4 Requirements

The primary functional requirement for our project is for our software simulation tool to be able to simulate communication between UAVs on a 5G wireless system. Our simulator will need to consider environmental factors such as weather conditions and avoid obstacles such as buildings or structures. The simulator will be open-source and free to access by others in the research community and beyond.

1.5 Intended Users and Uses

We expect our project to be used and referenced in academica and beyond. More specifically, we expect both students and faculty to be able to reference the work in this project, as well as implement and use the algorithms we will describe later in our project. We also expect researchers and engineers to be able to build off of our work on the project.

1.6 Assumptions and Limitations

Assumptions	Limitations
• Used by research professionals and network developers • Small scale development versus a large, ready-to-ship version	• Limited knowledge of networking • 2-semesters to finish project • Lack of previous knowledge with 5G

1.7 Expected End Product and Deliverables

Goals

- Understanding how to use OAI and other multi-domain simulators by downloading and running OAI and NPS in Linux Ubuntu. - Sept. 29th
- Integrating OAI with simulators to run drone simulations in 5G wireless systems. - Nov. 2nd.
- Extend existing networking algorithms for C-A2X (Cellular to Air Vehicles to Everything) - Feb 15th.
- Test networking algorithms using integrated OAI simulator for drones - March 15th.
- Perform field testing of a real-world drone delivery system and document research findings in a scholarly paper - April 19th.

Our expected deliverable for our first semester is getting used to OAI and UAV simulators. The main goal for the first semester is understanding and integrating OAI with multi-domain simulators. Once we are comfortable and understand how to use these programs we will be focusing on starting drone simulations for our second semester. We hope to use the experience from these simulations to prototype a drone and test in the real world. The discoveries and experiences of our project will then be documented as a scholarly article.

2 Project Plan

2.1 Task Decompositions

For this project, we have broadly separated our tasks into two categories: Software side, and hardware side. For our software, we expect to be improving upon the already existing algorithms that exist in OAI and other simulations, as well as being able to run multiple simulations simultaneously.
As for the hardware side, we're focusing on developing a way to implement our software algorithms and simulations into a microcontroller and casing, in order to prove that our software will work in a real-working prototype.

2.2 Risks And Risk Management/Mitigation

Our main risk we face, in the entirety of our project, is the commitment of time needed by all the group members to succeed in this project. For this, we plan to, again, run a Scrum-like system of task management, where each of us tackle a task, or story, for a sprint, or every two weeks. This way, we ensure each member has sufficient time to complete their tasks while not burning themselves out.
Another slightly different risk we face, is the recent emergence of 5G. While it provides a unique opportunity to shape 5G as we desire, it also leaves us with a lack of experts to turn to, as well as an overall inexperience to the subject and implementation. We plan to combat this by educating ourselves as much as we can, as well as documenting and sharing knowledge with one another as much as possible, to ensure that all parties in the group are as educated and knowledgeable of the project as possible.

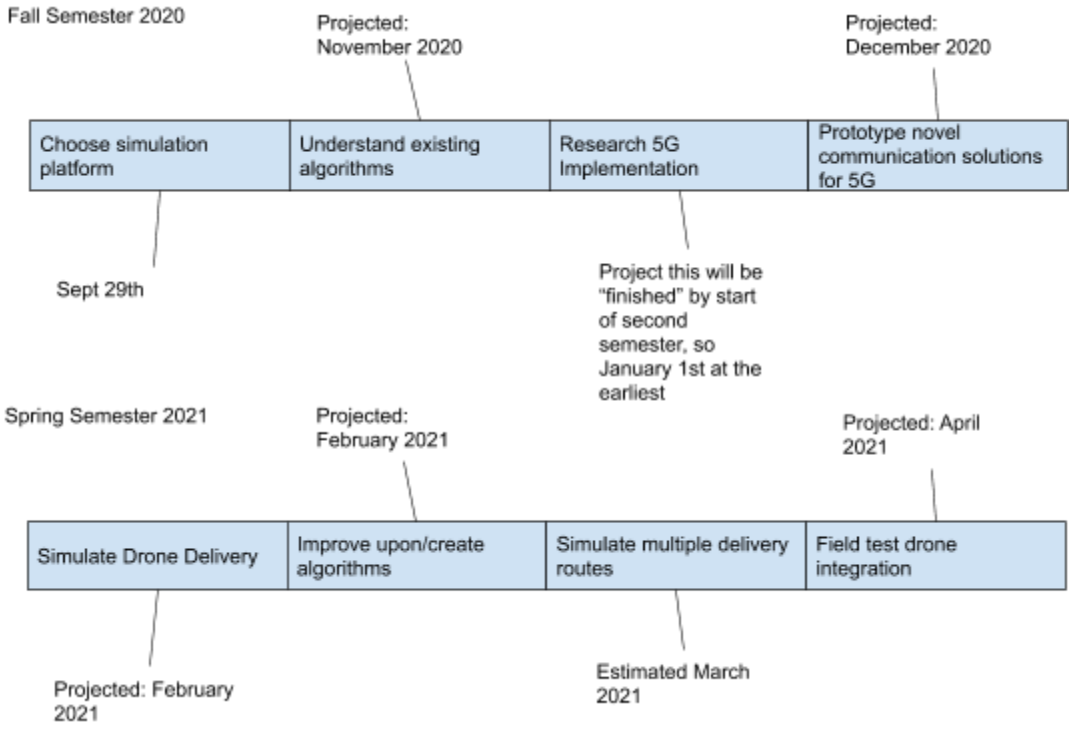
2.3 Project Proposed Milestones, Metrics, and Evaluation Criteria

Some key milestones for the project are as follows:

- Fall 2020:
    - Choose software Simulation/Platform
    - Refine OAI to support integrated OAI and drone simulation
    - Understand existing networking algorithms widely used in industry
- Spring 2021:
    - Create our own networking algorithm for communication among air vehicles
    - Get a single drone to simulate landing and departures to a destination
    - Simulate multiple different drone delivery routes
    - Compare different A2X Algorithms with simulation
    - Write a magazine article to summarize results (software/system development, research findings)
    - Field testing and drone delivery system

As we progress through our project, we will be measuring these against test cases ourselves, and our advisor, make for us. We'll also be evaluating this through three different processes, where the team will be going through any milestones hit, reviewing if it was a "success" or a "failure", then pass it onto the advisor. If the advisor clears it, the team will then review it once more with the advisor for the final yes or no. At that point, if all 3 cases are passed, the milestone will be considered a success.

2.4 Project Timeline/Schedule



(Fig. 2)

- Choose simulation platform
    - Experiment with different simulations and choose which best suits our project.
- Understand existing algorithms
    - Experiment with different algorithms, as well as understand what problem they were designed to solve
    - Determine what type of algorithms we will need to use and refine to complete our project
- Research 5G Implementation
    - Understand 5G architecture and related networking algorithms used in industry
    - Use best practices and solutions to integrate and implement 5G emulator with UAV simulator.
- Prototype novel communication solutions for 5G
    - Find different efficient ways to solve drone communication and path mapping using 5G network.
- Simulate Drone Delivery
    - Use integrated 5G/UAV simulation platform to simulate drone delivery routes
- Improve upon/create algorithms
    - Determine if we must begin the creation of our own algorithms to solve our simulation problems
    - After determination of algorithms we will use, begin the process of refining them to be used for specific purposes
- Simulate multiple delivery routes
    - Using our simulation, be able to simulate a delivery.
    - Be able to communicate with other objects (C-A2X) using 5G.

- Field test drone integration
    - Reach out to a professor doing related work with drone systems about conducting a field test

2.5 Project Tracking Procedures

We will be using an Agile framework using Scrum methodology for project management and software development. To do this we will be using Trello to create and assign tasks and insure that our team is meeting needs specified by our client. To manage our code we will be using GitLab and Git for version control. For communication, our team uses Microsoft Teams for messaging and weekly video conferences and Zoom meetings for calls with our client and faculty advisor.

2.6 Personnel Effort Requirements

Tasks	Hours
Research	Expect to spend about 30-40 hours on research, alone, for the project. This is because none of us have prior experience with 5G simulation, thus all of us need time to comprehend the subject. Total: 40 hours
Software Integration	This will be the bread and butter of the project. Thus, we expect to spend much of our time with the integration of simulation and development. Thus, throughout 2 semesters, we expect to spend around 5-10 hours per week on the integration.
Algorithm Design	Algorithm design is another large part and concept of our project. So, this will be very similar and hand-in-hand with our software integration. As such, we expect to spend around 5-10 hours on algorithmic design.
Field Testing	We will spend as much time as we can on this portion of the project. It is dependent on when we finish the project and we will spend the remaining time in the semester testing and using our software.
Documentation	Documentation will be done throughout the two semesters. We should spend roughly 2 hours each week working on scheduling, reports, and the design document.

(Fig. 3)

In terms of time spent on the project our team has decided that we will individually spend roughly 10-12 hours per week on our tasks. This is divided up into categories in the table above. The beginning will mostly consist of researching topics and getting more familiar with the tools/simulations that we will be using. First step will be the research portion of the project. We expect to spend 10 hours a week on this and it will end up being around 40 hours total. After this we will begin our design. This will be done in a parallel manner spending roughly 10 hours on either the software simulation or algorithm design. We expect to complete this portion of the project by the end of the Fall 2020 semester. After we are completed we will spend the remaining time testing our simulation and possibly setting up a real field test. We will also be spending about 10 hours a week on this. Finally, we have our documentation and we expect to spend roughly 2 hours a week making sure everything is organized and up to date.

2.7 Other Resource Requirements

Professor Zhang, our advisor/client, has been very kind in the lending of a possible group computer to use for this project, as well as providing a sizable list of academic resources used to get a better grasp on the project and what is necessary for us to be successful.

Again, later in the project we would like to possibly build a working prototype if time allows. At the time that we decide, we will make a list of parts and tools necessary for the build.

2.8 Financial Requirements

Almost all simulation software is free to the public and able to be used freely. As such, we do not foresee an immediate need for financial resources at this point in time.
Later in the project, we would like to possibly be able to build a prototype, if time permits. As such, we will gather a list of possible parts and resources needed to complete the prototype then.