

Fiber Optic and Mesh Networking Drone for Civilian Applications

Ethan Anderson, Ryan Dickson, Massimo Mancini, Brandon Singleton, Juan Zepeda

Faculty Advisor: Dr. Omar Rawdah

**Department of Electrical and Computer Engineering
Kennesaw State University**

I. ABSTRACT

Radio towers that are down for routine maintenance or unscheduled repairs can be a detriment to surrounding communities and businesses. To aid in this dilemma, a temporary replacement platform capable of sustained, stable signal transmission is necessary. Therefore, in this project, a fiber-optic, tethered Unmanned Aerial Vehicle (UAV) was developed alongside a wireless, self-healing network to extend communication range and reliability.

The hardware architecture consists of a custom-built drone using parts acquired online from multiple vendors and 3D printed elements. On the software level, BATMAN-adv acts as the mesh network protocol; for the UAV, MAVLink is utilized for fiber optic communication and control of motors and on-flight sensors. The communication scheme consists of three Raspberry Pis, one that routes data between the controller and the flight controller, as well as two that act as routers in the mesh network. This plan allows the drone to serve as a mobile node capable of hosting remote devices over significant distances while maintaining network integrity through 'self-healing' network protocols. The result is an aerial platform that improves network communication in spotty areas and serves as a prototype for a drone that could temporarily replace a network tower in the event of a tower outage.

II. INTRODUCTION

Reliable communication systems often fail in environments with signal obstruction, interference, or limited infrastructure, creating a need for a platform capable of sustained, stable signal transmission. Traditional solutions—including RF repeaters, satellites, free-space optical links, and battery-powered UAV relays—each address parts of the problem but introduce tradeoffs in latency, endurance, cost, or reliability.

A fiber-optic tethered UAV offers a stronger solution by combining continuous power delivery with high-bandwidth, low-latency, interference-resistant communication. While the most optimal implementation would integrate advanced hardware processing and fully optimized system architecture, constraints such as budget, development time, and project scope require focusing on a scalable proof-of-concept platform using available components. This approach demonstrates feasibility while leaving room for future expansion toward a fully optimized system.

III. FAA REGULATIONS

The FAA regulations related to flying UAVs were reviewed for adherence and compliance including:

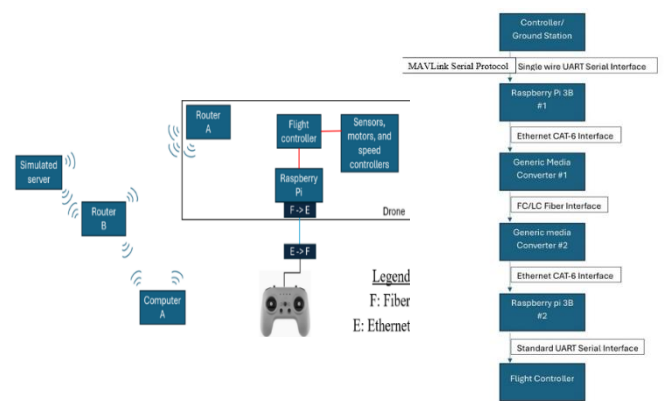
- Registration
- 14 CFR Part 107
- Airspace Rules
- Safety Guidelines
- Penalties

A Remote Pilot Certificate was acquired by one of the team members.

IV. SYSTEM DESIGN

A fiber optic drone system has several requirements in order to be useful and effective. This system includes a drone platform, a ground control station, and a fiber optic communication link between them.

The system is intended to provide stable flight control and reliable network connectivity while allowing the drone to function as a mobile node in a wireless mesh network or temporary access point for communication support.



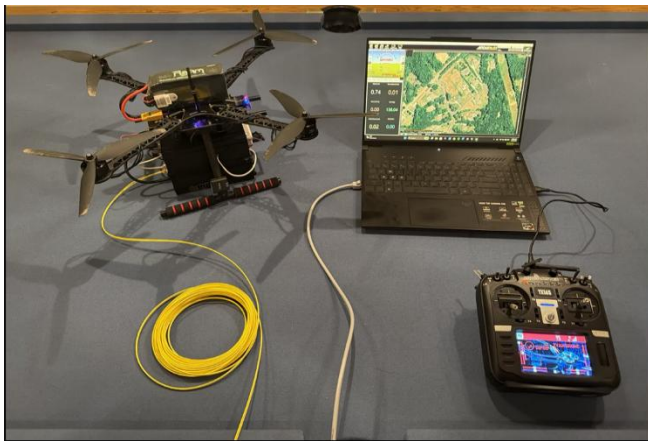
[Figure 1] System Block Diagram & Flowchart

The primary requirements of the system include reliable communication between the ground station and the drone through the ethernet and fiber optic tether, stable flight operation, successful data transmission, and scalability of the wireless mesh network. The drone must be able to receive control instructions through the fiber optic link while also functioning as a mobile node and wireless access point for temporary communication support.

A. Flight Communication and Ground Control System

The flight communication and ground control system consists of the ground control station, a Raspberry Pi 3B communication module, two ethernet-to-fiber media converters, the remote controller, and a computer running Mission Planner software. This subsystem allows the operator to send flight commands, monitor drone telemetry, and maintain real-time communication with the aircraft during operation.

The remote controller sends pilot inputs to the ground station computer through a universal serial bus (USB) connection using the Human Interface Device (HID) protocol. Mission Planner processes these control signals and converts them into MAVLink serial data, which is transmitted through the ethernet connection to the fiber media converter. The media converter sends this data through the fiber optic tether to the drone. On the drone side, a second media converter receives the optical signal and converts it back into ethernet user datagram protocol (UDP) packets containing MAVLink data. These packets are forwarded to the Raspberry Pi 3B, which acts as the communication bridge between the fiber link and the flight controller using universal asynchronous receiver-transmitter (UART) serial communication. This creates a stable and secure communication path between the pilot and the drone while supporting long-distance control and reduced electromagnetic interference.



[Figure 3] Ground station and tethered drone

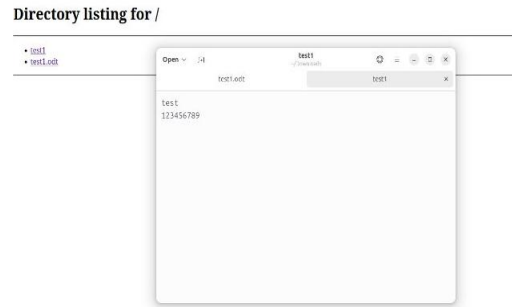
B. Mesh Network Communication System

The mesh network communication system consists of two Raspberry Pi 4 Model B units, Panda Wireless USB Wi-Fi adapters, and personal computers used as client devices. One Raspberry Pi is mounted on the drone to function as a flying router and mobile access point, while the second Raspberry Pi remains on the ground as a fixed router within the network.

The Raspberry Pi units communicate using the BATMAN-adv protocol through Layer 2 of the open systems interconnection (ISO/OSI) model, allowing both devices to function as routers and exchange data efficiently. The Panda Wireless adapters provide IEEE 802.11 wireless communication for external devices, such as laptops. This setup allows users to connect to the network through a secure Wi-Fi bridge.

The subsystem allows the drone to extend wireless coverage and provide temporary communication infrastructure in areas where normal wireless systems may be limited or unavailable. Although testing is performed using four total nodes, the

network is designed to be scalable and capable of supporting additional routers and client devices.



[Figure 4] Proof of file transfer within Mesh Network

C. Flight Control and Navigation System

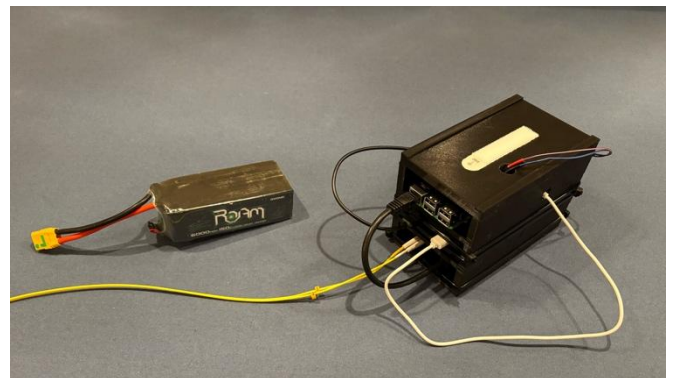
The flight control and navigation system consists of a flight controller, an electronic speed controller (ESC), a GPS and Compass module, and four brushless motors. These components work together to provide stable flight, navigation, and real-time maneuvering of the drone.

The flight controller serves as the main processing unit and sends digital motor speed commands to the ESC through an 8-pin connection. The ESC receives power from the battery and distributes controlled power to the motors using PWM signals to regulate motor speed and maintain stable flight. The GPS module provides positioning and orientation data to the flight controller, allowing accurate navigation and improved flight safety.

D. Power Distribution System

The power distribution system consists of a 22.2V battery, an electronic speed controller, and secondary 5V power supplies for onboard communication electronics. The battery provides the electrical power required for flight operation and communication. At the same time, the secondary supply furnishes the power for network functionality. The ESC provides power to the flight controller for stable flight management and motor control.

Separate 5V power supplies are used for the Raspberry Pi and the ethernet-to-fiber media converters to ensure stable operation of the communication system without interfering with the main flight electronics. This power distribution design improves reliability and helps maintain safe and consistent performance during tethered flight operations.



[Figure 5] LiPo Battery & Power Distribution System

IV. RESULTS & PERFORMANCE

The completed fiber optic tethered drone prototype successfully demonstrated flight operation, fiber optic communication capability, and wireless mesh networking functionality. Individual subsystems were tested independently before full system integration testing was performed. Final testing validated communication between the flight controller, Raspberry Pi systems, Mission Planner software, and mesh network devices. Performance metrics including thrust capability, flight stability, communication reliability, and networking functionality were evaluated.

A. Flight Performance

Initial flight tests revealed severe flaws in the drone's wiring and construction. At first, all four motors ran backwards and resulted in violent vibrations and the drone immediately flipped over after throttling up. Furthermore, the drone's external compass and GPS system were configured incorrectly. Excessive motor heat was also observed.

Further flight testing was conducted after completing calibration and firmware configuration, but the drone was

still constantly flipping over. As a result, parts were swapped out one by one until it was determined that none of the hardware components were faulty. After swapping to a wireless receiver, the drone eventually achieved controlled flight with pitch and roll oscillations at a frequency of roughly 3Hz during flight test #14. Troubleshooting has since continued and the cause of the oscillations was determined to be improper Proportional, Integral, and Derivative (PID) tuning. Further flight tests using a wireless receiver for control have helped with pitch and roll oscillations but have not eliminated them completely.

For the fiber system, communication was established and proved to be reliable but was not tested in flight due to fears of damaging the cable and other flight components during troubleshooting. This same result applies to the mesh network, where functionality of the system was proven, but in-flight testing was not done for the same reason above.

B. Flight Performance Results

Parameter	Result
Aircraft Weight	2900 g
Total Thrust	25.6 lbf
Thrust-to-Weight Ratio	5.82 : 1
Hover Throttle	41.5%
Estimated Flight Time	9.2 min
Hover Current Draw	110.4 A
Maximum Current Draw	228.0 A

[Table 1] Flight Performance Parameters & Results

The propulsion system utilized four 900 kV brushless motors powered by a 6S 6000 mAh LiPo battery pack. Performance calculations showed that the propulsion system provided sufficient thrust for stable flight and payload support.

The thrust-to-weight ratio of 5.82:1 confirmed that the drone had sufficient lift capability for stable maneuvering and payload operation. Hover throttle values also indicated that the propulsion system operated within safe performance limits during flight.

Initial testing revealed instability during hover and navigation. Multiple rounds of PID tuning and calibration adjustments were required to improve hover stability and reduce motor overheating. Migration from Betaflight firmware to Ardupilot firmware significantly improved overall system performance and compatibility with Mission Planner software.

C. Drone Control System Performance

The control subsystem successfully established reliable 2-way communication between the ground station computer, on board Pi, and the flight controller. Ethernet communication between devices functioned through fiber optic communication hardware. To achieve this a MAVLink signal is generated by the flight controller which is received by the ground station computer. The ground station running mission planner interprets the commands and generates a UDP signal that is sent over ethernet. The media converter receives this and converts the data to an optical signal that is then received by another converter which converts the information back over ethernet. This UDP is able to be received by the control Pi which then translates the data into a UART signal. This signal is finally received by the Speedy Bee f405v4 to control the drone. The process goes both ways from the ground station computer and flight controller.

Testing verified successful communication using MAVLink protocol integration with Mission Planner Ground Control Software, as depicted in figure 4.

D. Network Performance

The network successfully created a Local Access Network (LAN) with mesh capabilities, utilizing two Raspberry Pi 4's (Pi) microcomputers, a server computer and a client computer. The Pi's are running the BATMAN-ADV protocol to run the layer two routing. Alongside a bridge was created with a panda antenna for Wi-Fi broadcasting. Which allows the server and client computers to connect to network.

Because the routing is conducted in layer 2 commands, traceroute will not pick up the intermediary connections. To verify the self-healing property of the mesh network, a series of individual pings were conducted to the Pi's (routers) and server:

- The first round had both the routers connected, and every component was successfully pinged.
- Then router 1 was turned off and the server and router 2

were still able to be pinged.

- Next, router 1 was turned back on and router 2 was turned off which resulted in the server and router 1 returning the ping.
- Finally, both routers were turned off, and no other device was able to be reached to confirm that the computers were not communicating directly.

```

Administrator: Command Prompt
Approximate round trip times in milli-seconds:
  Minimum = 2ms, Maximum = 7ms, Average = 3ms

C:\WINDOWS\system32>ping 192.168.10.1

Pinging 192.168.10.1 with 32 bytes of data:
Reply from 192.168.10.1: bytes=32 time=2ms TTL=64
Reply from 192.168.10.1: bytes=32 time=1ms TTL=64
Reply from 192.168.10.1: bytes=32 time=1ms TTL=64
Reply from 192.168.10.1: bytes=32 time=1ms TTL=64

Ping statistics for 192.168.10.1:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
    Approximate round trip times in milli-seconds:
        Minimum = 1ms, Maximum = 2ms, Average = 1ms

C:\WINDOWS\system32>ping 192.168.10.2

Pinging 192.168.10.2 with 32 bytes of data:
Reply from 192.168.10.2: bytes=32 time=12ms TTL=64
Reply from 192.168.10.2: bytes=32 time=9ms TTL=64
Reply from 192.168.10.2: bytes=32 time=9ms TTL=64
Reply from 192.168.10.2: bytes=32 time=10ms TTL=64

Ping statistics for 192.168.10.2:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
    Approximate round trip times in milli-seconds:
        Minimum = 9ms, Maximum = 12ms, Average = 10ms

C:\WINDOWS\system32>

```

[Figure 6] Proof of Network

E. Cost Analysis

Description	Price (USD)
Flight Hardware	732.99
Communication Devices	272.10
Miscellaneous (SD Cards)	64.00
Total Cost	1,133.09

[Table 2] System Cost

V. FUTURE WORK

A. Power System Improvements

One of the primary limitations of the current prototype is operational flight time. The system currently relies on a 6S LiPo battery mounted directly on the aircraft, which limits sustained flight duration due to the combined weight of the drone platform and communication hardware.

Future improvements should focus on implementing a ground-powered tether system capable of supplying continuous power to the UAV during operation. This would significantly increase operational endurance and eliminate dependence on onboard battery capacity. Additional power optimization could also be achieved by removing the secondary 5V power source, improving power management and efficiency throughout the system.

Further adjustments to motor size would also improve efficiency, while better ESC tuning and monitoring systems would improve overall system reliability and flight performance.

B. Communication Hardware Optimization

The current system utilizes separate Raspberry Pi systems for flight communication and mesh network routing. While this modular design improved development flexibility and troubleshooting, future versions of the system could combine these functions into a single onboard computing platform.

Combining the Raspberry Pi 3B and Raspberry Pi 4B systems would:

- Reduce total payload weight
- Lower power consumption
- Simplify wiring and communication architecture
- Improve system compactness

Automation of the mesh networking startup process should also be improved to eliminate the need for manual bridge configuration during boot.

C. Flight Stability and Altitude

A flight controller like Pixhawk can provide good stability with its accompanying ESC.

Increasing the Thrust to Weight (T/W) ratio to make the aircraft lighter, especially with the added weight of a fiber optic canister fitted on board. The UAV needs to be powerful enough to carry the fiber cable spool.

D. Fiber Optic Tether System

A fiber optic tether was used with the current prototype to connect the ground control station (GCS) media converter to an onboard converter. Future work shall include an onboard fiber canister. This upgrade will give the UAV the capability to travel longer distances.

VI. CONCLUSION

A quadcopter drone was designed and built. A drone mesh network with 3 nodes was developed and tested successfully. Communication between the drone's FC and the GCS was established and tested with different communication methods. Communication via a fiber optic tether was established. After multiple attempts, the drone was able to be flown via wireless communication. Two of the three project KPI's were successfully met..

IV. ACKNOWLEDGEMENT

This project was completed to fulfill the requirements of the Senior Project course (EE 4800) at Kennesaw State University (Spring 2026). We are grateful to Dr. Omar Rawdah, Dr. Cyril Okhio, and Dr. Goran Novakovic for their guidance and support throughout this project

REFERENCES

- [1] “Application of fiber optics in aircraft control system & its development” (Atul Garg, Rezawana Islam Linda, Tonoy Chowdhury) (2014)
- [2] “Assessment of Drone Agricultural Spraying Operations Using Optical Fiber Sensors” (Maria Konstantaki, Emmanouil Anthoulakis, Stelios Christodoulou, Stavros Pissadakis) (2025)
- [3] “Cable Optimization and Drag Estimation For Tether-Powered Multirotor UAV’s” (Max Beffert, Andreas Zell) (2025)
- [4] “Tethered Unmanned Aerial Vehicles-A Systematic Review” (Miguel Nakajima Marquez, Sandro Augusto Magalhães, Filipe Neves Dos Santos, Hélio Sousa Mendonça) (2023)
- [5] “Fiber-Optic Drone Technologies: A Multidisciplinary Review from Communication Fundamentals to Military Applications” (K. Yalçın) (2025)