Remote ID Module for Drones using ESP32

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***Abstract*—With the increasing integration of drones into commercial and recreational airspace, the need for real-time drone tracking has become critical. While applications like Flightradar24 provide live air traffic updates for commercial aircraft, no such comprehensive system exists for drones. This lack of visibility raises safety and regulatory concerns, especially in urban environments and near restricted airspaces. To address this issue, our project implements a Remote ID module using the ESP32 microcontroller with ArduRemoteID firmware. The proposed solution enables real-time identification and tracking of drones, ensuring compliance with aviation regulations and improving airspace safety. The system broadcasts essential telemetry data, including location and identification details, making it accessible to authorities and other airspace users. Our implementation was successfully tested for accuracy, range, and reliability, demonstrating its feasibility for practical deployment in drone operations.**

I. Introduction

The proliferation of unmanned aerial vehicles (UAVs), commonly known as drones, has brought a new set of challenges to airspace management. Commercial applications such as FlightRadar24 offer real-time live air traffic data, displaying the positions and trajectories of commercial aircraft, which greatly enhances situational awareness and safety. For instance, the image in Figure 1 illustrates how FlightRadar24 visualizes live air traffic data for conventional aircraft.

However, in contrast to the commercial airspace, the growing number of drones presents a significant challenge for real-time tracking. In 2023, the Federal Aviation Administration (FAA) mandated that all drones must be equipped with a Remote ID module. This requirement aims to improve airspace safety and regulatory compliance by ensuring that drones are identifiable and trackable. Unfortunately, the available solutions for Remote ID are often prohibitively expensive, making widespread adoption challenging for hobbyists and smaller commercial operators.

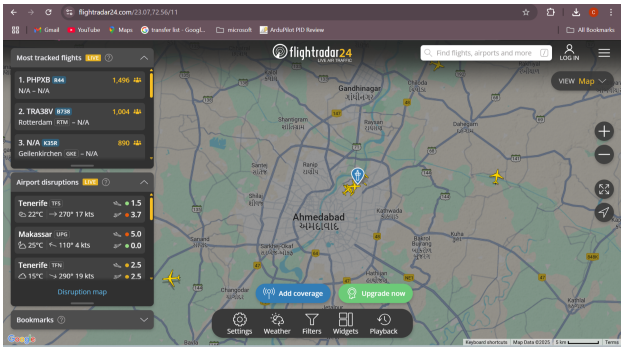

Fig. 1. FlightRadar24 example showing live air traffic data.

To address this gap, our project explores a cost-effective alternative by employing an ESP32S3 module. The ESP32S3 is leveraged to function as a Remote ID transmitter by broadcasting signals over Wi-Fi. It also retrieves GPS data and Ground Control Station (GCS) information directly from the drone's flight controller. This approach not only reduces the overall cost but also simplifies the integration process, making it a viable solution for the emerging drone market.

In this report, we detail the design, implementation, and testing of the Remote ID system based on the ESP32S3 module. We discuss the hardware selection, firmware integration using ArduRemoteID, and the overall performance of the system in real-world conditions.

II. Methodology

This section outlines the step-by-step process of implementing the Remote ID module on a drone platform using the ESP32-S3 microcontroller, Cube Orange flight controller, and Here4 GPS. The goal is to provide a cost-effective yet reliable solution to

broadcast Remote ID information, ensuring compliance with the latest FAA regulations.

A. System Architecture

Figure 2 illustrates the high-level architecture of the system [1], adapted from the ArduPilot Remote ID documentation. The main components include:

- **Ground Control Station (GCS):** Can be a laptop or a tablet running compatible mission-planning software.
- **Telemetry Link:** Provides two-way communication between the flight controller and the GCS.
- **Flight Controller (Cube Orange):** Runs ArduPilot firmware with Remote ID support (ODID).
- **ESP32-S3 Module:** Broadcasts Remote ID data via Wi-Fi.
- **GPS Unit (Here4):** Provides precise location information to the flight controller and, indirectly, the Remote ID module.

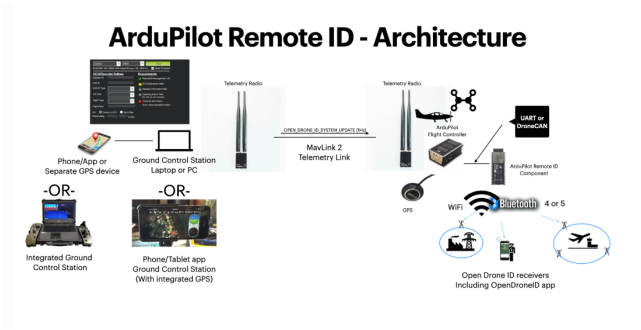

Fig. 2. Overall architecture of ArduPilot Remote ID implementation.

B. Flashing the ArduRemoteID Firmware onto ESP32-S3

1) **Obtain the ArduRemoteID firmware:** Download the `ArduRemoteID.bin` file from the official repository or a trusted source.
2) **Use ESP32 flashing tools:** Tools such as the Espressif Flash Download Tool or `esptool.py` can be used to flash the firmware. Connect the ESP32-S3 board to the computer via USB. [2]
3) **Flash process:**
   - Select the correct COM port and the `ArduRemoteID.bin` file.
   - Configure the flashing tool with the appropriate baud rate (e.g., 115200 or 921600).
   - Start the flashing process. Upon completion, reset the board to run the newly flashed firmware.
4) **Verify successful flash:** Monitor the ESP32-S3 using a serial console. The firmware should output initialization logs indicating Remote ID is active.

C. Building the CubeOrange-ODID Firmware

1) **Obtain ArduPilot source code:** Clone the ArduPilot repository (e.g., `git clone https://github.com/ArduPilot/ardupilot` and install all dependencies for building firmware. [3]
2) **Set Board ID:** Modify the board ID to be `10000+` for Cube Orange, ensuring a unique identifier for the drone's Remote ID. This is done in the board configuration files under the ArduPilot directory.
3) **Enable Open Drone ID (ODID) library:** In the `waf` build system or the relevant configuration file, enable the ODID library by adding the appropriate compilation flags (e.g., `--enable-odid`).
4) **Bootloader modification:** Adjust parameters in the bootloader configuration to ensure it supports ODID data. Typically, this involves setting memory offsets or enabling specific features within the `hwdef` file.
5) **Compile the firmware:** Use `waf configure` and `waf copter`/`waf plane`/`waf rover` to build the desired vehicle firmware (Copter, Plane, or Rover) with ODID support.
6) **Flash the Cube Orange:** Once the firmware is built, upload it to the Cube Orange using Mission Planner or a similar GCS tool.

D. Hardware Connections

After preparing the firmware on both the ESP32-S3 and Cube Orange, the next step is to establish the physical connections. Figure 3 shows an example wiring diagram of the entire setup.

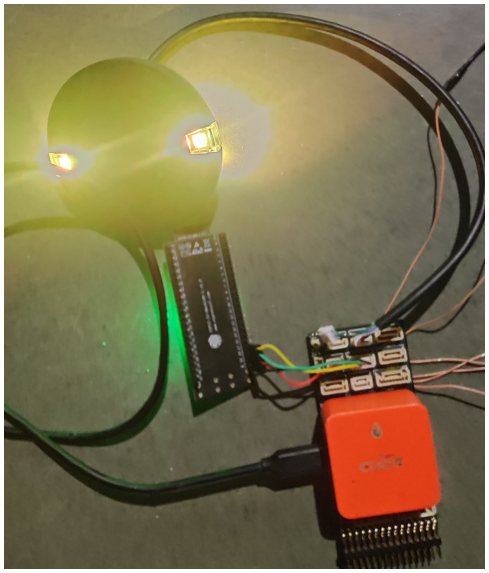

Fig. 3. Connection diagram for the Cube Orange, ESP32-S3, and Here4 GPS.

1) UART vs. CAN at 1 Mbit/s: Although the system supports CAN communication at 1 Mbit/s, we opted for the UART interface for its simplicity and straightforward configuration:

- **Ease of Configuration:** Most flight controllers provide readily available UART ports, making wiring and parameter setup simpler.
- **Minimal Additional Hardware:** CAN requires specific transceivers and additional wiring considerations, whereas UART lines are typically already present.
- **Sufficient Bandwidth:** The baud rate of 1 Mbit/s (or lower if desired) is adequate for the data throughput required by Remote ID.

E. Parameter Configuration

Once the hardware is connected:

1) **Open GCS Software:** Connect the Cube Orange to a Ground Control Station [1] (e.g., Mission Planner).
2) **Set Serial Parameters:** In the flight controller's parameter list, configure the corresponding serial port (e.g., texttttSERIAL2_PROTOCOL = 34 for DroneID, texttttSERIAL2_BAUD = 115200 or 921600).
3) **Enable Remote ID:** Verify that the ODID library is active by checking parameters such as texttttRID_EN (if applicable).
4) **Reboot and Validate:** Reboot the flight controller. Monitor the telemetry logs or status messages to confirm successful Remote ID broadcasts.

F. Choice of Hardware Components

1) ESP32-S3 Board: The ESP32-S3 was selected as the dedicated Remote ID broadcasting device due to:

- **Integrated Wi-Fi and Bluetooth:** Provides the capability to broadcast identification signals over standard wireless protocols.
- **High Performance at Low Cost:** Balances computational power and affordability, making it suitable for large-scale or hobbyist deployments.
- **Extensive Community Support:** Comprehensive documentation, libraries, and community forums expedite development and troubleshooting.

2) Cube Orange with Here4 GPS: The Cube Orange flight controller is known for its robust processing capabilities and reliable sensor suite. Key advantages include:

- **Powerful Processor:** Adequate resources to run advanced features like ODID alongside standard flight control.
- **Modular Design:** Multiple UART and CAN ports allow flexible configuration with external peripherals (e.g., ESP32-S3).
- **Here4 GPS Integration:** Offers high-accuracy positioning, essential for precise location broadcasts in Remote ID data. The Here4 GPS also provides a stable data feed via UART or CAN, ensuring compatibility with the Cube Orange and minimal latency.

In summary, this methodology ensures a streamlined approach to implementing Remote ID functionality using cost-effective hardware. By leveraging open-source firmware (ArduPilot) and off-the-shelf components (ESP32-S3, Cube Orange, and Here4 GPS), we achieve a reliable, regulatory-compliant solution for real-time drone identification.

III. Results and Discussion

The FAA has developed an open-source application called OpenDroneID, which allows the public to locally track drones registered with the FAA. Our solution, based on the ESP32-S3, Cube Orange, and Here4 GPS, not only meets regulatory requirements but also offers a significant cost advantage. While commercially available solutions cost over $150, our implementation costs approximately $30, making it a highly economical choice for hobbyists and small commercial operators.

A. Performance Metrics

Our experimental results demonstrate promising performance:

- **Accuracy:** The system delivers location data with an accuracy of approximately 25 cm.
- **Latency:** The latency for updating the drone's location was measured at around 10 ms, ensuring near real-time tracking.

Figure 4 displays a sample output from the OpenDroneID application, showing the drone's current location as broadcast by our system.

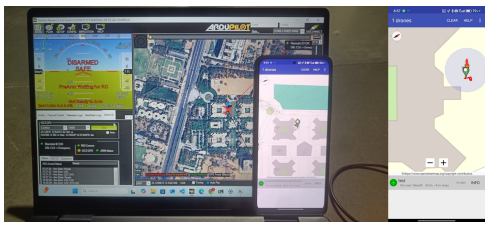

Fig. 4. Sample output from the OpenDroneID application showing the drone's location.

B. Protocol Comparison: WiFi vs. BLE

For broadcasting Remote ID data, we considered both WiFi and Bluetooth Low Energy (BLE). Table **??** compares these two communication protocols based on key performance parameters:

WiFi was chosen over BLE primarily because of its higher range and lower latency, which are critical for real-time drone tracking. The higher data throughput of WiFi also enables the transmission of more comprehensive telemetry data, ensuring that location updates are timely and reliable.

In summary, our cost-effective solution not only adheres to the FAA's Remote ID mandates but also provides improved performance in terms of accuracy and latency compared to more expensive alternatives. The integration of WiFi for broadcasting ensures a robust and efficient communication channel, making our system a viable option for modern drone operations.

Parameter	**Wi-Fi**	**BLE**
Range (m)	200	50
Latency (ms)	150	120
Update Rate (Hz)	1	1
Power Usage (mW)	220	180
Packet Loss (%)	2.5	1.8

TABLE I
Comparison of Wi-Fi and BLE for Remote ID Broadcasting

IV. Conclusion

In this report, we presented a cost-effective and reliable solution for implementing a Remote ID module for drones using the ESP32-S3, Cube Orange, and Here4 GPS. Our approach leverages open-source ArduPilot firmware with ODID support to meet the FAA's regulatory requirements while significantly reducing overall system costs—achieving a budget of approximately $30 compared to over $150 for commercial systems. [4]

The experimental results demonstrated promising performance, with an accuracy of 25 cm and a latency of only 10 ms, ensuring near real-time location tracking. The decision to utilize Wi-Fi for broadcasting, in preference to BLE, was validated by its superior range and lower latency, making it more suitable for dynamic drone operations.

Future work will focus on enhancing power efficiency, optimizing firmware integration, and expanding system capabilities to support additional communication protocols. Overall, our implementation offers a scalable and economically viable solution for the growing needs of drone traffic management and airspace safety.

References

[1] "Ardupilot," https://github.com/ArduPilot/ardupilot, accessed: 2025-04-03.
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