Poster: A Multi-Drone Platform for Empowering Drones' Teamwork

Seungho Yoo, Kangho Kim, Jongtack Jung, Albert Y. Chung,
Jiyeon Lee, Suk Kyu Lee, Hyung Kyu Lee, and Hwangnam Kim
School of Electrical Engineering, Korea University
Seoul, Rep. of Korea
{pen0423, mybalam2k, skylover89, aychung, jiyeon524, sklee25, schk00, hnkim}@korea.ac.kr

ABSTRACT

The rapid development of UAV technology has opened up numerous applications. Further, cooperating drones[1] possess a great potential in various areas of applications. Yet, there has not been a platform for a fleet of drones. It is rather difficult to control multiple drones through a single ground control station. In fact, drones need to consistently exchange flight information to maintain the formation of the fleet and follow the commands given from the GCS. Thus, drones need a robust network established among the fleet to provide a fleet control. In this paper, we propose Net-Drone, a multi-drone platform for applications that require cooperation of multiple drones. Net-Drone is equipped with strong network functionalities to provide a control system for a fleet of drones. Through case studies conducted with a prototype implementation, the proposed system is demonstrated. Video of the conducted case study can be found in [5].

Categories and Subject Descriptors

C.2.1 [**Computer-Communication Networks**]: Network Architecture and Design; J.2 [**Computer Applications**]: Physical Sciences and Engineering

General Terms

Design, Implementation, Experimentation, Performance

Keywords

Unmanned Aerial Vehicle (UAV), Drone, Fleet Control

1. INTRODUCTION

With the rise of the unmanned aerial vehicle (UAV), it is common to see UAV related applications nowadays. Even though drone technology has been initiated as a military purpose, it is expanding its usage to both the industry and the academia. Google initiated the Project Loon [2], DHL and Amazon [1] are starting drone delivery system, and numerous researchers are conducting researches related to drone applications. Yet, most of the drone related products, services and projects regard only a single drone, and what a single drone can accomplish is somewhat limited by the physical features. For instance, a multi-rotor can fly only for a short period of time and the payload of most drones is considerably limited. Deploying multiple drones can overcome the hardware limitations, but simultaneous management of multiple drones presents multiple challenges.

Efficiently and effectively coordinating multiple devices to complete a single task is always an important issue in many fields. Further, in case of drones, the numbers can lengthen the time of flight, widen the sensing and communication range, or provide higher accuracy and robustness to a given task. In this paper, we propose Net-Drone, a multi-drone platform where multiple drones work cooperatively to complete a given task. We have designed and implemented the prototype of Net-Drone to ascertain the potential of the proposed platform.

Net-Drone is not just an application for multiple drones, but a platform that can support various applications that require multiple drones. Our proposed platform converts the hassle of planning mission and controlling multiple drones one-by-one into a unified control system where multiple drones are controlled as a single fleet.

2. DESIGN

In this section, we present the description of the Net-Drone. In order to manage a fleet of drones, it is crucial to establish and maintain communication among the drones and with the ground control station (GCS). However, solely equipping an access point (AP) onto a drone is not sufficient. The fleet of drones is not only establishing communication with the GCS, but it needs to collect and share the information of the drones within the fleet for management purposes. Furthermore, with this communication feature, we can further utilize the proposed platform by designing a novel application with the network assistance from the GCS and a fleet of drones. Thus, the communication medium of each drone needs to communicate with the drones within the fleet and the GCS. Based on this networking feature, a drone fleet management platform can control the entire fleet and provide necessary information to the user. With this in mind, we prototype Net-Drone primarily based on the communication within the fleet and establish a communication between the GCS and the fleet for management purpose within the platform. Figure 1 elaborates the architecture of the proposed platform. Net-Drone consists of multiple drones and a GCS, and both are equipped with core modules.

Operation flow. Based on the platform architecture in Figure 1, the operation flow is as follows. The planning of a fleet mission is devised through the GCS. The core modules of the GCS interpret

[1]In this paper, we refer to all types of UAVs as drones.

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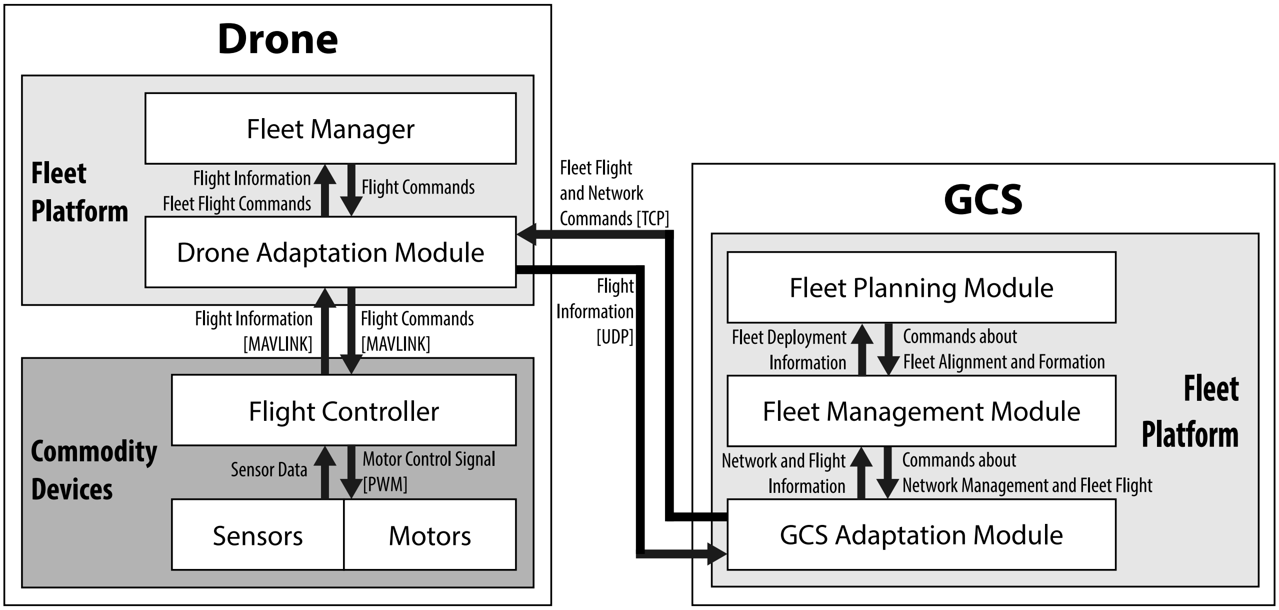

Figure 1: Platform architecture.

the deployment planning into multiple drone tasks. The tasks are sent to each drone either directly or through multi-hop communication function of Net-Drone. Upon task reception, each drone sets its position in the fleet and the destination of the fleet. After deployment, the fleet manager keeps track of its position and continuously sends flight commands to the flight controller. The flight controller flies the drone by managing the motor control signal.

Drone modules. The core module that flies the drone is the flight controller. The flight controller is equipped with sensors that are required for automated flight such as GPS, IMU, and acoustic sensors. Flight information, including various sensor data, is sent to the fleet manager which will be used to create flight commands and other flight information. The flight controller generates motor control signal according to the flight commands.

The fleet manager is the module that processes the high level instructions transmitted from the GCS. High level instructions are converted into flight commands that are sent to the flight controller. The flight commands that the fleet manager transmits are simple locations where the drone needs to be located at. Not only does the fleet manager converts the high level instructions into flight commands, but also maintains the formation of the fleet. According to the flight information received from the flight controller and the neighboring drones via the drone adaptation module, the fleet manager calculates its precise location in the fleet and the distance between the neighboring drones. If the formation of the fleet is distorted or if two drones are located too close to each other, the fleet manager can schedule to move the drone to maintain the shape of the fleet or the distance between the drones.

The drone adaptation module delivers data from one module to another and provides network functions. When a drone receives flight commands from the fleet manager or the GCS, the commands need to be translated into a message that the flight controller can interpret. Net-Drone aims to support various flight controllers and thus requires drone adaptation module to translate commands into a flight controller specific message. The drone adaptation module is also equipped with network functionalities. Since drones tend

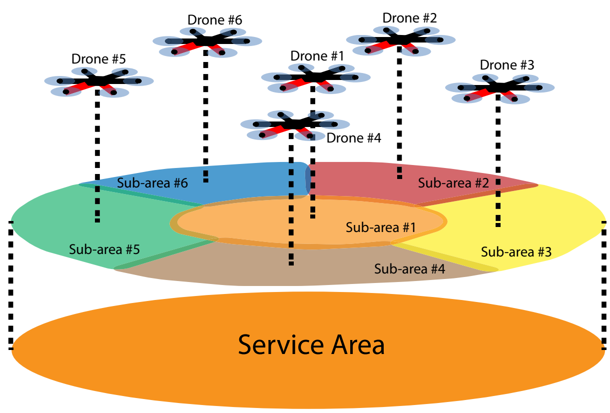

Figure 2: Deployment scenario.

to experience high mobility, non-robust network will result in frequent disconnections and unstable routing. Also for the drones to perform a fleet flight, drones need to consistently exchange flight information. Therefore, a strong network function is crucial for drones to successfully perform a fleet-wise flight. The drone adaptation module enables robust connectivity among the drones and also between the drones and the GCS.

GCS modules. The GCS is the user-interactive management system for Net-Drone. Through GCS, users can set the movement of a fleet as well as the behavior of each drone after deployment. The GCS can connect to multiple drones and send control messages. The GCS adaptation module is equipped with network interfaces, which allows GCS to connect to multiple drones using the multi-hop communication function of Net-Drone.

The mission planning scheme of Net-Drone GCS allows users to easily set service areas for multiple drones. Figure 2 demonstrates the mission planning scheme of the drone fleet. User can set the general service area by interacting with the fleet planning module

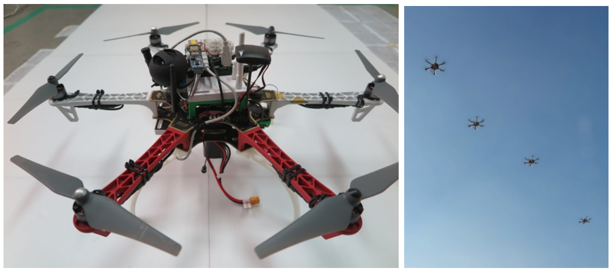

Figure 3: Drone prototype and fleet flight using Net-Drone.

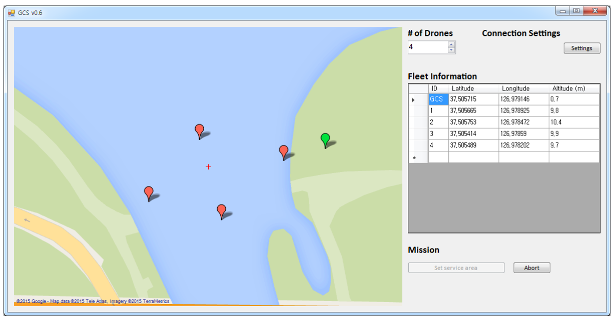

Figure 4: GCS prototype.

of the GCS. The service area information is sent to fleet management module, and the fleet management module divides the area into sub-areas according to the number of drones in the fleet. Each drone in the fleet is assigned to a sub-area which acts as its service area. The GCS adaptation module sends the sub-area information and fleet formation information to each drone, and case specific controls are handled within the drone. Sub-area information and fleet formation information are both critical data, and thus this information is transmitted using TCP to guarantee the delivery of information. On the other hand, the flight information sent from the drones is somewhat less important and the system can tolerate some data loss. Therefore, UDP is used for delivering flight information of drones.

3. IMPLEMENTATION

Based on the architecture design of the proposed platform, we developed and deployed a prototype of Net-Drone. In this section, we describe the details of the implementation and its application scenarios.

Prototype implementation. Figure 3 shows a drone prototype and multiple drones flying as a fleet using Net-Drone. We adopted the Pixhawk autopilot [4] of 3D Robotics for the flight controller, and Odroid U3 of HardKernel for the fleet manager and the drone adaptation module. Pixhawk and Odroid U3 are connected via USB to UART module. MAVROS, installed on the fleet manager, takes the role of translating the MAVLINK messages [3] sent from the flight controller and also the vice versa. Fleet manager runs ROS to provide real-time data to the flight controller. Odroid U3 is equipped with a Network Interface Controller to grant network capability to the drone adaptation module.

Figure 4 shows the implementation of GCS prototype. Our GCS prototype was implemented from scratch with C# language on a Samsung Series 8 Laptop with a 2.5 GHz Intel Core i7 processor. An wireless AP is connected to the GCS to establish connections with the drones.

Applications. We conducted a couple of case studies to show the potential of Net-Drone. For the first case study, we conducted a landscape mapping application. Unlike the traditional landscape mapping using a single drone, we used Net-Drone to control three drones, each equipped with a camera, to perform landscape mapping simultaneous. Using Net-Drone for the landscape mapping application, we were able to successfully map an area with multiple drones.

The second case study is a network service provision application (refer to the video in [5]). Four drones were used in the case study and each drone is equipped with an extra NIC to provide connection with objects other than the drones. With the case study, we were able to confirm that a fleet of drones controlled by Net-Drone is capable of providing a network service over a wide area, which is an application that cannot be accomplished with a single drone.

Other than the two case studies we conducted, Net-Drone can be applied to the following applications: surveillance, cooperative delivery, and efficient sensor data gathering.

4. CONCLUSION AND FUTURE WORK

In this paper, we designed and implemented Net-Drone, a platform for a drone fleet control platform. The fleet based control system is successfully constructed with our design, and applications using it is demonstrated. Net-Drone can widen the application of drones by enabling multiple drones to accomplish missions that were not suited for a single drone. The applications of Net-Drone is not limited to the applications depicted in this paper, but can be further expanded. In our future works, we plan to investigate such applications and provide a more thorough evaluation of Net-Drone.

5. ACKNOWLEDGMENTS

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