UAV Networks in Rescue Missions

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ABSTRACT

Small-scale unmanned aerial vehicles (UAVs) have received high attention by the robotics community for delivering sensory data of limited size. Yet, the communication capabilities of off-the-shelf UAVs are insufficient for high volume data, such as images and videos. In this demo, we present our networking solution to this problem, residing next to the auto-pilot, and able to create an ad-hoc multi-hop network of UAVs. We show the effectiveness of our implementation in two representative scenarios of rescue missions: (i) the establishment of end-to-end connectivity for a smartphone in an area with network outage and (ii) the delivery of a high-resolution video of a supervised area from a flying UAV to the ground station.

Categories and Subject Descriptors

C.2.1 [**Computer-Communication Networks**]: Network Architecture and Design—*Wireless communication*

Keywords

Unmanned Aerial Vehicles, 802.11n, Aerial Links

1. INTRODUCTION

Unmanned aerial vehicles (UAVs) play an increasingly important role in time-critical search and rescue (SAR) missions. Here, UAVs can provide a swift first overview of the target area for 3D mapping or spot a missing person. This is viable, as state-of-the art UAVs can have an optional light-weight high-resolution camera [4]. However, this large-size data cannot be delivered in real-time by means of, e.g., the 802.15.4 communication protocol used in modern solutions to control the UAVs. The immediate availability of bulk picture and video data at the ground station would be a breakthrough in SAR missions, traditionally carried by humans and dogs. For instance, delivering high-resolution images of the supervised surface to rescuers is a "must-to-have" necessity to spot an injured individual in short time. In this contribution, we present our multi-hop UAV networking solution to this problem in two representative use cases: establishing end-to-end connectivity to the smartphone of a missing person, and, streaming high-resolution videos of the area of interest.

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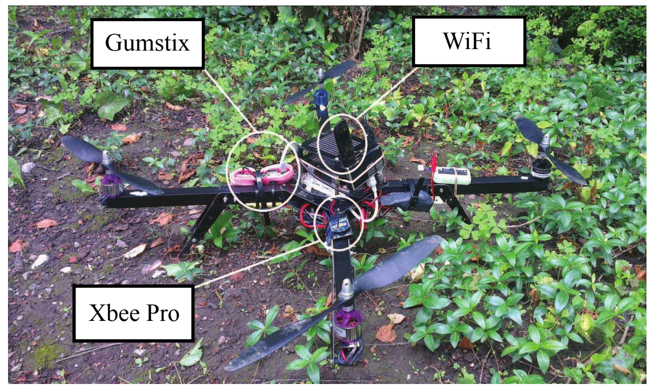

Figure 1: The UAV: Arducopter.

2. FLYING PLATFORM

We employ two "Arducopters" as our UAVs, which are quadrocopters equipped for outdoor flights (see Figure 1). Their firmware is based on Arduino [1]. For each UAV, an electrical motor drives its four propellers and enables flying. A lithium polymer battery is used that provides flight autonomy of up to 20 minutes. We operate the UAVs at the default cruise speed of about 4.5 m/s and at a safe altitude (up to 100 m).

The main electronic system of the UAV is the autopilot, which integrates a GPS unit, pressure sensors, and inertial sensors. The autopilot enables the UAV to take off and land autonomously and to navigate through defined way-points. Way-points can be set through a graphical user interface (GUI) on the ground station. We have selected QGroundControl as GUI [5] since it is open source, easy to extend, and well-documented.

3. HYBRID NETWORK

In SAR missions, UAV networks should support two different types of data: one are light-weight status, sensor data, and commands, and the other are bulk data. On the one hand, commands and status information demand only low throughput but reliable links, and on the other hand, transferring images or videos demands high throughput links. We therefore propose to use a hybrid wireless network consisting of two wireless networks as follows [2, 3]:

XBee-PRO 802.15.4: The communication link from the ground station to every UAV is based on XBee radio operating in 2.4 GHz frequency band, which provides a reliable link at low bandwidth (up to 250 kbps) but long range (up to 1.2 km). The XBee network is used for control messages and short sensor and status information.

Wi-Fi 802.11n: Further, the UAV is equipped with a Wi-Fi 802.11n module. The system is extended by a Gumstix Overo Tide computer-on-module running a Linux distribution and residing next to the autopilot. The 802.11n USB dongle is attached with the help of an additional expansion board. We selected a Linksys 802.11 USB dongle coming with Ralink 3572 chipset due to its Linux compatibility, dual 2.4 and 5 GHz bands capability, and light-weight design. We could achieve a throughput of up to 80 Mb/s in our embedded setting on the aerial links between UAVs.

4. DEMO

We envision two main SAR scenarios, wherein we expect that UAV networks will play a key role in the early future: (i) UAVs will allow to establish network connectivity in areas with communication outage and (ii) UAVs will supervise an area and deliver video and image data for monitoring and 3D mapping of the area. Our setup for the demonstration is a multi-hop ad-hoc network of UAVs. The following components will be leveraged:

- A ground station: We use a laptop that communicates with the XBee-PRO 802.15.4 and Wi-Fi 802.11n protocols and runs a customized graphical mission planner (QGroundControl) to control the movement of each quadrocopter and to monitor the activity in the sector controlled by each UAV.
- Two Arducopters: Quadrocopters are employed, which use the hybrid network for communication. An on-board camera is further added to the quadrocopters' payload for taking pictures and videos.
- A smartphone: If the owner is injured, an Android application running on the smartphone broadcasts HELP messages including the phone's GPS position.

We demonstrate the successful run of the SAR scenarios as follows (using video recordings accompanied by a live demonstration of the major components):

1. One quadrocopter takes a video from an altitude of tens of meters of the search area and streams it to the ground station by relaying via the other quadrocopter (i.e., in multi-hop).
2. A victim with a smartphone is missing in an area and therefore two quadrocopters are sent to look for the person. The smartphone continuously broadcasts HELP messages (through Wi-Fi). When a UAV is in communication range, it receives the HELP messages and forwards them to the ground station. At the ground station, the GPS coordinate of the victim is shown on the map and human rescuers can act to rescue the person.

The demonstration exemplifies how the open source code for the pilot, the communication stack, and the GUI enables us to test scenarios. Thus, our setting can easily be adopted to a wider set of UAV network use cases. Further, the multi-hop UAV network itself can be monitored in real-time, supported by the client software QGroundControl. By sending light-weight commands through the (directly-connected) Xbee channel, the UAVs can exchange link and GPS position information with the ground station without the need (and the delay) of passing through the Wi-Fi multi-hop network. For instance, one can command to stop image streaming or can force the Wi-Fi communication to adjust or re-establish links. The flexibility in network control is a major benefit of our hybrid wireless communication architecture.

5. CONCLUSION

We demonstrate that the tight integration of communication and sensing functionalities of UAVs supports a variety of missions. To disclose this potential, we show two representative examples of SAR scenarios which may benefit from the network of UAVs. In the first scenario, we establish connectivity for an injured person through her smartphone's helper app, and in the second one, video-streaming is used to scan an area and spot injured and missing persons. Thanks to our hybrid network solution consisting of XBee (control channel) and multi-hop Wi-Fi 802.11n (high volume data channel), we achieve a flexible network to support rescue applications, which makes the employment of UAV networks attractive for rescue missions.

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