Testbed for Fast-Deployable Flying WiFi Network

Jean-Christophe Zufferey
SenseFly

Karol Krużelecki,
Alberto Jiménez-Pacheco,
Bixio Rimoldi,
and Stefano Rosati
Information Processing Group
EPFL

Dario Floreano
Laboratory For Intelligent Systems
EPFL

I. Motivation

EPFL's Information Processing Group (IPG) and Laboratory for Intelligent Systems (LIS), in conjunction with SenseFly (a LIS spin-off) recently started a project aimed at developing a testbed to experiment with self-organized wireless networks carried by autonomous unmanned aircrafts. The idea is to use drones developed by SenseFly to carry the infrastructure of a self-organized WiFi network for easy and rapid deployment. The network can be used to connect people on the ground (e.g. rescue people in case of catastrophe) and/or to send back to a data center the information collected by sensors. The sensors might also be carried by some of the drones. The drones have a high degree of autonomy. In particular, they are capable of carrying out a missions and land without human intervention.

In this talk we present the state of this ongoing project that involves many challenges, including resource management, mobility management, self-organization, and scalability. All these challenges exist for the wireless network as well as for the network of drones. We focus on the former.

II. The Hardware

The communication hardware is carried by eBee drones [1] developed by SenseFly. The drones are fixed-wing aircrafts with an electric motor and integrated autopilot capable of flying with winds of up to 12 m/s, at a cruising speed of up to 57 km/h, with an autonomy of up to 45 minutes. In case of emergency, they can be remotely controlled up to a distance of 3 km via a ZigBee link connection. Within this distance the flight mission can be modified on the fly if necessary. The autopilot has access to an inertial measurement unit, a barometer, a pitot-tube for airspeed, an optical-flow sensor and GPS receiver. The eBee also carries a Gumstix Overo Tide [2] computer with an Ångström Linux distribution [3] and a standard USB WiFi card. We use this embedded computer to establish the wireless network. A serial connection between the auto-pilot module and the embedded computer allows us to access the sensors attached to the autopilot (including the GPS reading) and to give commands to the autopilot, e.g. modify the aircraft mission according to routing needs. Thanks to its small dimensions and weight (under 630 g), flying eBees are not considered a threat: In many countries (e.g. Switzerland) they can be flown without specific authorization.

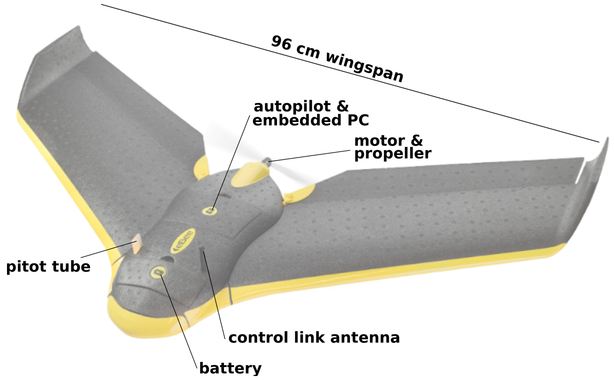

Fig. 1. SenseFly eBee drone

III. Routing Protocol

The flying ad-hoc network is characterized by high-mobility nodes. In order to guarantee a reliable communication, the routing protocol must be able to rapidly react to network topology changes. In our study, we considered two routing protocols: BABEL [4] and Optimized Link-State Routing (OLSR) [5], which have been specifically developed for ad-hoc networks. We found that OLSR suits better our needs. This is mostly due to its higher flexibility that allows us to optimize the protocol for our high-mobility network.

IV. Field Experiments

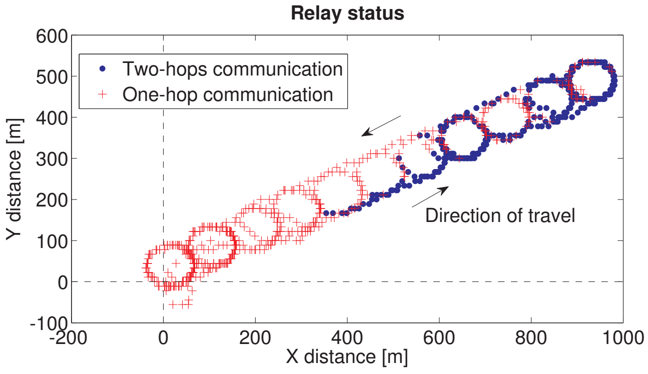

Fig. 2. Sequence of circular way-points of radius 50 m at various distances from the destination (at the axis origin), with the relay drone positioned half-way.

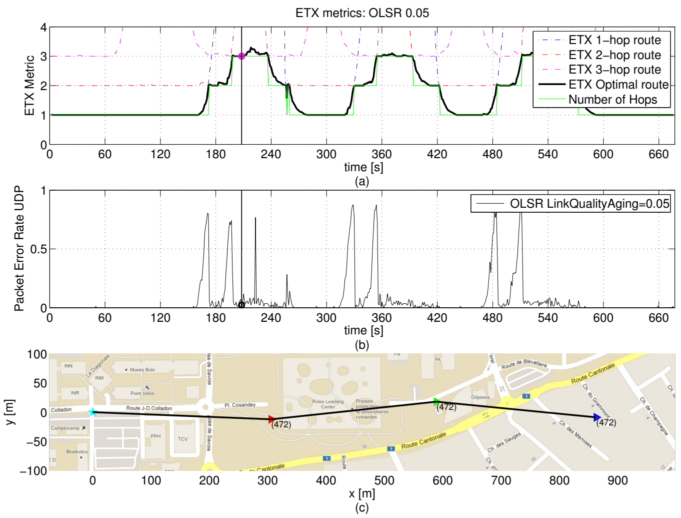

Fig. 3. Snapshot of the emulator: (a) ETX metric versus time; (b) PER versus time; (c) Communication links.

In January 2012 we performed a first round of experiments involving a drone equipped with a camera, a second drone serving as relay, and a laptop on the ground. We were able to achieve a throughput of more than 2 Mbps video streaming up to a distance of 1 km. See Figure 2 and [6].

V. Emulation Platform

Field experiments are time-consuming, require the involvement of a few people, transportation, and costly equipment. This has motivated the development of an emulation platform that integrates all the testbed aspects, in particular a flight simulator, the wireless channel model, the IEEE 802.11 protocol, and routing.

The flight simulator is programmable the same way as the drones and provides an fairly accurate description of the actual in-flight behavior. From the flight simulator we can export positions, speeds, and orientations, used by the channel propagation model. The same parameters can be exported from actual flight missions. As for the propagation model, in principle we can use any model we can describe mathematically. Currently we have implemented the free-space propagation model, a 2-ray channel model, and the 802.11 TGn channel model [7]. We emulate the IEEE 802.11 MAC layer using the Extendable Mobile Ad-hoc Network Emulator (EMANE). EMANE is an open-source framework, mainly developed by Naval Research Laboratory for real-time modeling of mobile network systems. All network layers except the MAC and the physical layer use the actual implementation for the Linux machine hosting the emulation. Figure 3 shows a sample snapshot of the graphics produced by the emulator. In this case we have set up a multiple-hop scenario illustrated in Figure 3(c), consisting of a mobile source (on the right), two mobile relays, and a fixed destination (on the left). The solid black line represent the multi-hop communication link. In Figure 3(a) we plot the expected transmission count (ETX) metric computed by the OLSR daemon versus time. Figure 3(b) shows the Packet Error Rate (PER) between the source and the destination. Routing is handled by the OLSR protocol with *"Link Quality Aging"* parameter set to 0.05 seconds and *"Hello Interval"* parameter set to 1 second.

VI. Short-Term Future Plans

For the communication part, our next goal is to compare simulation results to field tests. The outcome will be presented at the workshop.

Acknowledgment

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