A5.2. Implement localization algorithm on UAV and entire constellation

A5.2 Istraživanje izvedivosti lokalizacije koristeći vrijeme propagacije signala

D5.2. Report: UAV pilot localization using control signal time of arrival analysis in RF spectrum

D5.2. Izrađen izvještaj o lokalizaciji pilota drona koristeći analizu vremena propagacije kontrolnog signala u RF spektru

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Introduction

Unmanned Aerial Systems (UAS) on the highest level are made of Unmanned Aerial Vehicle (UAV) and control systems (CS). Although UAV are capable of autonomous flight on a preset path, most are controlled using CS using various realtime communication technologies. Those technologies utilize a specific part of the EM spectrum. For example, DJI UAV uses a 5.8GHz channel for communication.

Issue of localization of UAV or CS can be solved using various approaches:

- Signal strength
- Angle of arrival
- Fingerprinting
- Time of arrival

Every of these are well defined in scientific and engineering literature. In the scope of UAV/CS localization all can be used except fingerprinting because of the nature of applications. If UAV is used in a constant environment, closed space, then fingerprinting localization could be feasible.

This report will analyze the feasibility of *Time of Arrival* approach.

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State of the Art

Peng and Sichitiu state that range-based schemes rely on the range measurements (received signal strength (RSS), time of arrival (TOA), time difference of arrival (TDOA) and angle of arrival (AOA)) among the nodes[1]

Localization methods using time difference are discussed in detail in [2], [3] and there are around 500 000 papers that mention time of arrival or time of flight localization. The concept is well defined and most notable research proves feasibility, Humphrey and Hendley have demonstrated sub-meter precision[4] using super resolution mechanisms.

Haute et al. used a time of arrival approach for localization of robots inside industrial complexes[5]. Indoor environment is made of metal and results with a lot of reflections and multipaths. Because of that signal strength approach would not be that feasible. They calculated location using radio wave propagation, they reported 50% of increased accuracy compared to GPS systems up to 0.15m.

Isaacs et al. proved the feasibility of TOA approach in localization of wireless sensor networks. Furthermore, they provided guidelines for sensors placement for maximized precision[6]. Chan et al. used TOA in non-line of sight scenarios, thus including reflections and multipaths. They conclude and identify significant errors compared to line of sight configuration.

Official WiFi protocol has introduced Wi-Fi positioning system (WPS) that allows positioning of WiFi devices in an area. It uses time of arrival to determine location of nodes.

Conclusion

Observed research proves successful application of TOA in localization. Some authors suggest that TOA is more precise in open space with a clear line of sight.

UAV pilot localization certainly falls into that category where UAVs usually operate in open space. This would assume that TOA is feasible. However, in order for TOA to operate it is necessary to carefully measure time on both sides: sender and receiver. If UAV and CS use the latest WiFi WPS protocol, TOA could be possible. Unfortunately, major manufacturer DJI uses proprietary communication protocol OcuSync and LightBridge that do not provide timing information into the signal and are, usually, encrypted. TOA requires precise time measurement of start of signal and the time when signal is received. In theory multiple UAVs could be arranged in 3D grid (e.g. cube) that could use time measurements based on location and differences of reception, because the wavelength of 5.8GHz is around 0.05168835m UAV locations should be substantially precise and prone to any environmental disturbances which makes TOA virtually impossible. On the other side, if communication technology is open and can be modified TOA would be feasible. However, **in case of localization of intruder UAV pilot, TOA is not feasible approach**. RSS would be a more feasible solution. And even AOA might be more feasible

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if scanning UAVs are equipped with directional RF scanning equipment and angle changes can be simulated using UAV Z axis rotations.

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