Development and demonstration of UAVs detection methods via Cellular Networks

Summary

Thomas Johann Seebeck Department of Electronics at School of Information Technologies, Tallinn University of Technology, Estonia, has an opening for a PhD project on the Development and demonstration of new methods for UAVs detection via Cellular Networks.

Research field:	Information and communication technology
Supervisors:	Muhammad Mahtab Alam Ivo Müürsepp
Availability:	This position is available.
Offered by:	School of Information Technologies Thomas Johann Seebeck Department of Electronics
Application deadline:	Applications are accepted between October 01, 2024 00:00 and October 25, 2024 23:59 (Europe/Zurich)

Description

UAVs piloted through the cellular network are not widespread yet, although the international standardization work is ongoing already from some time [1]. Currently, regulations in most countries only allow for operating drones when there is Visual Line of Sight (VLOS) between the drone pilot and the drone. It is expected that Beyond Visual Line of Sight (BVLOS) operations will be allowed soon, provided there is a reliable Command and Control (C2) link to the drone [2]. Ongoing advancements in cellular technology, such as the rollout of 5G networks, are expected to address some of these current limitations. As the technology evolves, the use of cellular networks for drone control is likely to become more prevalent, especially in applications where the benefits outweigh the challenges. There are already some commercial service providers available. For example, Botlink offers drone control from anywhere in the world via an LTE network. Works have begun exploring the usage of LTE for Drone to Drone communication [3], or developed testbeds for cellular driven UAVs [4].

From technology trends for 5G and beyond, base stations will have increasingly better sensing capabilities as the standard evolves, which can be leveraged to gather different types of information about the connected users. Using these, it is possible to differentiate what kind of hardware is connected by analyzing the doppler profile of the connected user or other Channel State Information (CSI) metrics such as angle of arrival. Cities are typically a no-fly zone in European countries, due to privacy and safety concerns involved in UAV operation, due to this, the presence of a terminal connected to the cellular network which appear to be flying above such areas could be relayed to law enforcement forces which could take prompted actions to stop illegal UAV operations. This simple approach, however, disregards the presence of legitimate drones which could be regular hobbyist drones or logistic drones.

In such a complex scenario, a malicious drone may even attempt an impersonation attack, to attempt to sneak past exclusion zones by posing as a harmless logistic drone. Another approach that becomes possible is the usage of packet sniffing through the available network interfaces to identify which of the connected users is a UAV. For this standard compliant metadata present in the packets of control channels could be leveraged as well as the aggregation of such data in the core network. Particularly, thanks to this latter, we are able to simultaneously monitor the entire territory covered by the cellular service. By leveraging location services, users' locations and movements can also be tracked and, using AI algorithms, they can be classified according to their type and tracked.

There are several network metrics that can be utilized to help detect unauthorized UAV access and distinguish it from regular user equipment (UE). Some of these network metrics include:

1. Signal Strength and Quality: UAVs typically face unique channel conditions when connecting to a base station, which. By analyzing quality metrics, such as Received Signal Strength Indicator (RSSI), Reference Signal Received Power (RSRP) and Signal-to-Noise Ratio (SNR), anomalies in the channel experienced during transmission can be identified, indicating the presence of an unauthorized UAV.

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2. Mobility Patterns: UAVs often exhibit different mobility patterns compared to regular UEs. They may have more linear and predictable movement trajectories, unlike ground based UEs which are constrained by city topology. By analyzing the mobility patterns of connected devices, algorithms can identify suspicious behavior that aligns with UAV movement characteristics. Furthermore, a malicious actor may be moving towards a specific target, whereas a regular drone may have a different pattern.
3. Traffic Patterns: UAVs may generate different traffic patterns compared to regular UEs. They may exhibit specific data transfer patterns or protocols that are distinct from typical UE traffic. They are likely piloted through either an HTTPs websocket or VPN tunnel, however they generate distinctive traffic due to the need to have real time controls and video streaming for FPV drones. By analyzing traffic patterns, including packet size, frequency, and timing, algorithms can detect anomalies that may indicate the presence of an unregistered UAV.
4. Coverage data: Monitoring specific interfaces may yield useful information to distinguish malicious users from regular ones. This involves extracting information from SIM card registration/ID, localization data, mobility patterns (handovers), and interfaces to the user plane function (UPF).
5. Airborne Localization: One distinct characteristic of UAVs is their presence in the air. By utilizing airborne localization techniques, such as angle of arrival estimation or trilateration based on signal timing/strength measurements from multiple base stations, it is possible to identify devices that are airborne and distinguish them from ground-based UEs.

Above mentioned metrics can be leveraged to detect the UAV.

Objectives and Tasks

- The objective of this PhD project is to develop new research on UAVs detection. The specific tasks are as follows:
- Setup hardware platform (UAVs and networks) and collect data through measurement campaign to generate different metrics.
- Devise and validate new techniques and algorithms for the UAV detection; Research will focus on developing algorithms in line with real-life use-cases by generating diverse traffic patterns, various metrics will be researched;
- Development of a prototype demonstrator and optimize the framework in terms of key communication network performance parameters using AI-based or analytical techniques;
- Contribute to dissemination i) deliverables and reporting, ii) seminars and workshops;
- Publish results as quality impact papers including impact factor journals, flagship conferences and focused workshops and in standardization activities.

Prerequisites

- A strong background in wireless communications 5G and beyond, applied data science; machine learning (supervised & unsupervised learning) and statistical learning, Deep, federated learning etc.;
- Experience and interest for real-life implementation, testing and validation of ML techniques;
- Excellent knowledge of languages such as, python, (Embedded) C, Java, as well as tools like R, Matlab etc.;
- Self-motivated and committed person who takes ownership of their project;
- Excellent writing skills.

Tallinn University of Technology is an equal opportunity university. Female applicants are particularly encouraged to apply.

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References:

[1] 3GPP, "TR 36.777, Study on Enhanced LTE Support for Aerial Vehicles (Release 15)," 2017.
[2] J. Wigard, R. Amorim and I. Z. Kovács, "Controlling drones over cellular networks," Nokia, 2022.
[3] A. Fakhreddine, C. Raffelsberger, M. Sende and C. Bettstetter, "Experiments on Drone-to-Drone Communication with Wi-Fi, LTE-A, and 5G," in 2022 IEEE Globecom Workshops (GCWkshps), Rio de Janeiro, 2022.

[4] O. Takács, T. Kovács, I. Drotár and G. Wersényi, "Technical Feasibility and Design Challenges of Unmanned Aerial Vehicle based Drive Testing on Cellular Networks," in 2022 IEEE 1st International Conference on Internet of Digital Reality (IoD), Gyor, Hungary, 2022.

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