Unmanned Aerial Vehicle Vertical Applications' Trials Leveraging Advanced 5G Facilities

5G!Drones use cases

Workshop 1 - Empowering Transatlantic Platforms for Advance Wireless Research

Jussi Haapola (University of Oulu), June 18th, 2019

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## 5G!Drones Objectives – for motivation

<table>
<thead>
<tr>
<th>Objective 1</th>
<th>Analysis of the performance requirements of UAV verticals’ applications and business models in 5G.</th>
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</thead>
<tbody>
<tr>
<td>Objective 2</td>
<td>Design and implementation of the 5G!Drones software layer (or system) to execute UAV trials</td>
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<td>Objective 3</td>
<td>Design a high-level scenario descriptor language to run and analyse the results of the UAV trials</td>
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<td>Objective 4</td>
<td>Design and implementation of 5G!Drones enablers for UAV trials and operations.</td>
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<td>Objective 5</td>
<td>Validate 5G KPIs that demonstrate execution of UAV use cases</td>
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<td>Objective 6</td>
<td>Validate UAV KPIs using 5G</td>
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<td>Objective 7</td>
<td>Advanced data analytics tools to visualise and deeply analyse the trial results, and provide feedback to the 5G and UAV ecosystem</td>
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<td>Objective 8</td>
<td>Dissemination, standardisation and exploitation of 5G!Drones</td>
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</table>
Use case scenarios – UAV traffic management

Unmanned aerial systems (UAS) traffic management (UTM).

Common for all use cases and scenarios.

In the EU, UTM systems (level U1: E-registration, E-Identification and Geo-awareness) will be mandatory in every EU country by 2019.

Public security and safety concerns, privacy concerns, and vulnerability to cyber-attacks are some of the major challenges to the adoption of the UAS traffic management systems.

- It should be noted that drone applications will require extremely low end-to-end latency, in the order of milliseconds, in order to operate in a safe and secure way.

**Scenario 1: UTM command and control application**

The network needs to provide

- a cross-domain network slice for UAV traffic control – a uRLLC slice able to reduce delay and having a high priority;
- in addition to low latency and high priority, this slice should ensure the authentication of users as well as the integrity and often confidentiality of the conveyed control traffic – in particular, end to end encryption of the slice can be a solution that would protect a third party from taking control of the drone;
- a UAV control applications hosted at the edge; and
- the possibility to have D2D communications in licensed or unlicensed spectrum.
Use case UTM (cont.)

Scenario 2: 3D Map and supporting visualisation/analysis software for UTM

* Complex shapes of cell tower radiation patterns along with sophisticated signal dissipation (at the buildings, high vegetation areas and uneven terrain) create a non-trivial signal distribution at urban areas.
  - video stream and other sensor input sent by the drones to populate dedicated 3D mapping software or
  - create and update a digital twin world, leveraging the UTM applications, in order to help the drone operators and flight planners to fly their drones and fleets in the best possible 5G service conditions, when low latency and high quality live video transmission are required.

* The network needs to provide
  - two cross-domain network slices for UAV traffic control and drones’ data:
    - a uRLLC slice able to reduce delay and having a high priority for UAV traffic control, and
    - an eMBB slice (no priority) for the data sent by drones;
  - a drone control application and parts of 3D mapping software for the Virtual Reality world application hosted at the edge.
UAVs can play a vital role in assessing damage and providing relief as they have the ability to take on roles where relief workers and manned vehicles fall short.

- high-resolution images and perform 3D mapping.
- identify hotspot areas.
- A swarm of UAVs can cover more ground quickly and efficiently.
Use case – saving lives

**Scenario 1:** Monitoring a wildfire

- UAVs equipped with HD cameras can be used for streaming HD video to a remote application hosted at the edge.
- Using AI tools, the remote application analyses the video to predict the direction of spreading of wildlife to the firefighters so they can pay immediate attention to those areas and also avoid using the potentially dangerous routes for rescue operation.
- The network needs to provide:
  - two cross-domain network slices for UAV traffic control and drones’ data, i.e.,
    - a uRLLC slice able to reduce delay to offer the appropriate level of security and isolation, and having a high priority for UAV traffic control and
    - an eMBB slice with high-priority for the HD video stream sent by the drone.
  - Given the nature of the monitoring operation, a strict isolation between these slices spreading until the radio segment should be ensured with a particular attention to be drawn to the security of this control slice; depending of the conveyed HD video traffic and its copyright requirements a controllable level of security can be added to the eMBB slice.
  - Edge cloud resources to host both the drone control application and a data analysis server.
    - The instantiation of resources and their dynamic configuration will leverage the virtualised 5G architectures we rely on in this project.

Use case – saving lives

Scenario 2: Disaster recovery

-uAVs are fitted with 5G small cells and can be carried close to the disaster area using a mobile ground station.

-uAVs can interconnect and communicate with the ground station over direct D2D links.
  • Allowing for the rapid deployment of a wireless backhaul in situations where capacity is needed
  • These networks allow both victims and emergency workers to communicate when it is most important.

-The network needs to provide
  • two cross-domain network slices for UAV traffic control and drones’ data, i.e.
    • a uRLLC slice able to reduce delay and having a high priority for UAV traffic control and
    • an eMBB slice with high-priority for the data sent by drones;
  • edge computing resources to host both the drone control application and a data analysis server;
  • enabled D2D communications in unlicensed or licensed spectrum.
Use case scenarios – Situation awareness

Large infrastructures like bridges, 5G cellular towers or power distribution networks are required to be inspected on a regular basis.

• The current methods of inspection can be inefficient, risky and expensive.

Environmental monitoring or smart agriculture scenarios involve remote inspection and potentially the deployment of a large number of sensors.

• Aerial measurements in order to ensure better weather forecasting and pollution assessment.

Use case – Situation awareness

Scenario 1: Infrastructure inspection

- A drone or a swarm of drones can be deployed, carrying onboard cameras, lidars, or any specific sensors in order to get awareness on the situation.

- All these drones would feed their data to the analysis application hosted at the MEC server.

- In addition to the software for the control and the management of the UAVs, additional software modules will be used from the control of the IoT devices onboard.

- These software components will be deployed at a control center or instantiated at an edge cloud exploiting MEC capabilities.

- The network needs to provide
  - two cross-domain network slices for UAV traffic control and drones’ data, i.e.,
    - a uRLLC slice able to reduce delay and having a high priority for UAV traffic control and
    - an eMBB slice (no priority) for the data sent by drones;
  - edge computing resources for the drone control application, the data analysis servers and IoT control modules.
  - Finally, separate security slice will be developed to provide Security-as-a-Service over 5G!Drones.
Use case – Situation awareness

Scenario 2: UAV-enhanced IoT data collection

A number of terminals with sensing and communication capabilities will be installed on the ground, and flying base stations will be deployed to enhance the transmissions of ground IoT devices.

In particular, the flying drones will act as mobile IoT base stations, communicating with the deployed devices using technologies such as NB-IoT.

The data will be relayed over the wireless backhaul from the UAV to the core network, where mMTC should also be supported by the deployed end-to-end slice.

The network needs to provide

- two cross-domain network slices for UAV traffic control and drones’ data, namely
  - a uRLLC slice able to reduce delay and having a high priority for UAV traffic control, and
  - a mMTC slice (no priority) for the data relayed by drones.
- edge computing resources to host both the drone control application and a server for data aggregation and analysis. 5G!Drones will also develop watermarking algorithms for data protection.
Use case – Situation awareness

Scenario 3: Location of UE in non-GPS environments

- One flying UAV carrying a 5G UE with sensors flies around areas of interest to collect data for the 5G service area coverage.
- Based on collected information, the 5G UE location application can analyse the UAV location.
- Collected data will be further analysed to create a map of 5G service area coverage. 5G-based positioning information will be fused with GPS information so that positioning will always be available.

The network needs to provide

- In this use scenario the network needs to provide two cross-domain network slices for UAV traffic control and drones’ data:
  - a uRLLC slice able to reduce delay and having a high priority for UAV traffic control;
  - an eMBB slice (no priority) for the data sent by drones;
- 5G UE location and 5G service area coverage analysis application hosted at the edge.
Use case scenarios – Connectivity during crowded events

Using an on-demand swarm of UAVs equipped with 5G small cells can solve this challenge by providing better coverage resulting in fewer dropped calls and better Internet connectivity to people attending the events.

Since in this use case drones are flying over a crowded area, reliable control of drones (i.e., flying capabilities and residual battery life) is needed.
Use case – Crowded events

Scenario 1: Connectivity extension and offloading

The UAV will onboard a small cell, and coordinate with the macro cell, to offload traffic to the 5G Core Network.

Secure communication and authentication are vital to communicate with large variety of devices.

The network needs to provide

- two cross-domain network slices for UAV traffic control and drones’ data:
  - a uRLLC slice able to reduce delay and having a high priority for UAV traffic control;
  - an eMBB slice (no priority) for the data sent by drones.
- Secure communication and high-speed authentication will be also considered under both cross-domain network slices.
## Use cases summary – 5G

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<th>5G KPI</th>
<th>5G service(s)</th>
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<td>• End-to-end latency of &lt; 1ms</td>
<td>uRLLC</td>
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<td>1</td>
<td>• 1000 times higher mobile data volume per geographical area.</td>
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<td>2</td>
<td>• 1000 times higher mobile data volume per geographical area.</td>
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<td>• 10 to 100 times more connected devices.</td>
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<td>• Time of deployment; Number of controllable sensors/actuator; Perceived Quality of Experience (even in the presence of obstacles); Latency vs. range; Area covered; Security; Broadcast to close UAVs; Broadcast to all UAVs</td>
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<tr>
<td><strong>UAV traffic management 2</strong></td>
<td>Same as above.</td>
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<td><strong>Safety 1</strong></td>
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