2018 IEEE Global Communication Conference

Authors : Oussama Bekkouche, Tarik Taleb and Miloud Bagaa

Abu Dhabi, United Arab Emirates, 2018, pp. 1-6. doi: 10.1109/GLOCOM.2018.8647421

UVAs Traffic Control based on Multi-Access Edge Computing

Date : 2019 / 12 /30

Name : 陳文遠

StudentID : 108064535

CONTENT

INTRODUCTION

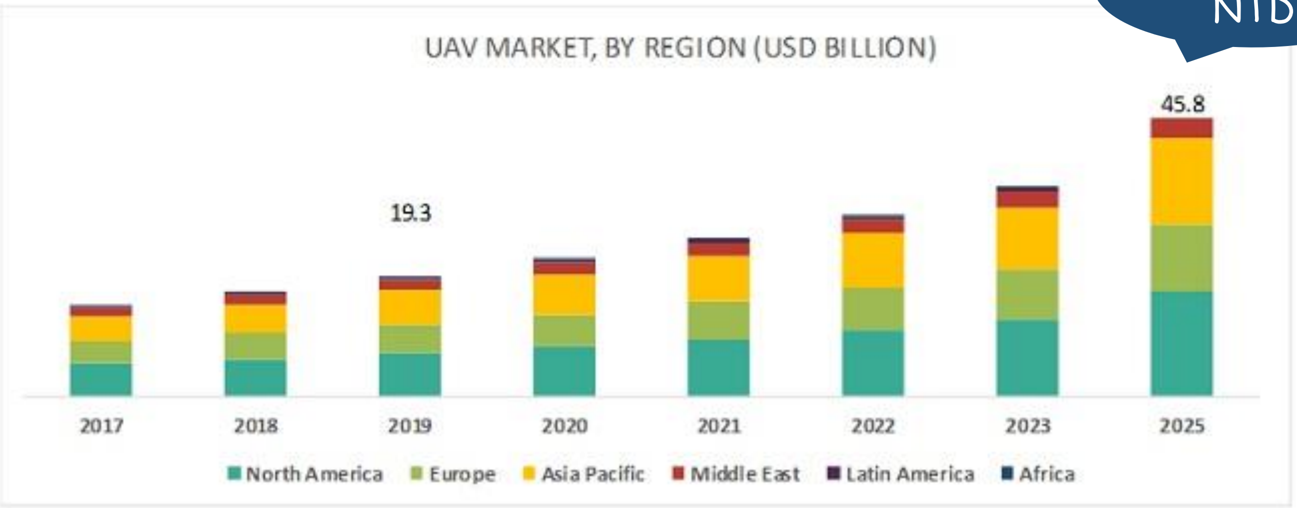
Why UAV ?

- UAV is widely used.

  - Military Reconnaissance
  - Inspection of Infrastructures
  - Smart Agriculture
  - Traffic Management
  - Border surveillance
  - Cargo delivery

- UAV's market is expected to reach $45.8 billion by 2025.

1.4 trillion NTD



Air Traffic Management (ATM)

- Each UAV is manually and individually operated (or use pre-define program).
- In challenging environments, we must keep UAV stayed in Visual-Line-of-Sight of pilot.
- Rely on voice communication between air traffic controllers and pilots.

That’s not designed to handle the expected high density of UAVs traffic.

UAV Traffic Management (UTM)

- Used to handle the high density of UAVs traffic.
- Mitigate the risk of collision among small UAVs, flying in uncontrolled airspace.
- A standard UTM must offer are the identification, the localization and the steering of UAVs.
- Use cellular mobile networks to support the communication between UTM service and UAVs.

- Advantage：
  - Scalable
  - Secure
  - Ready-for-use

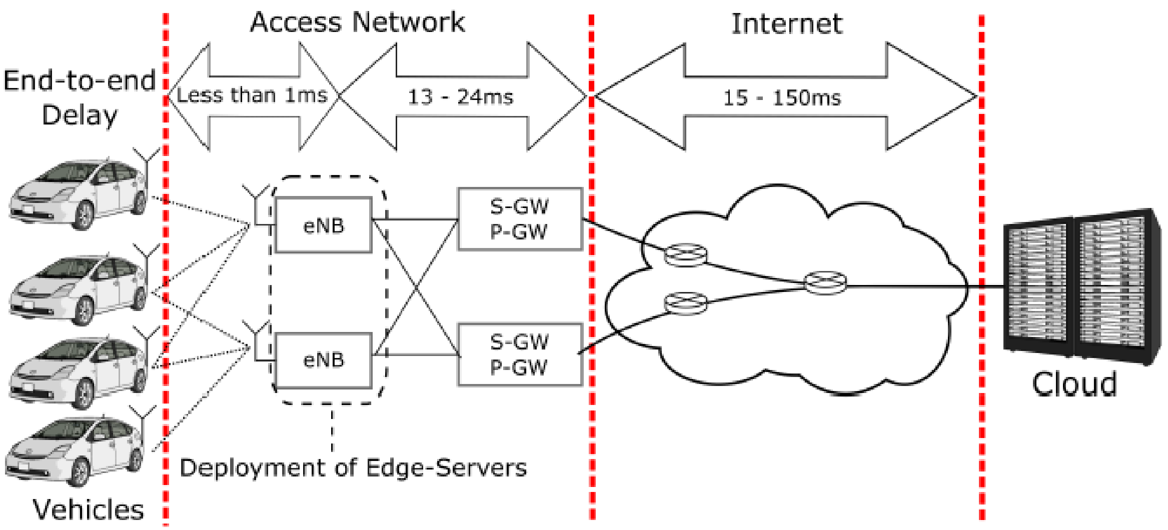
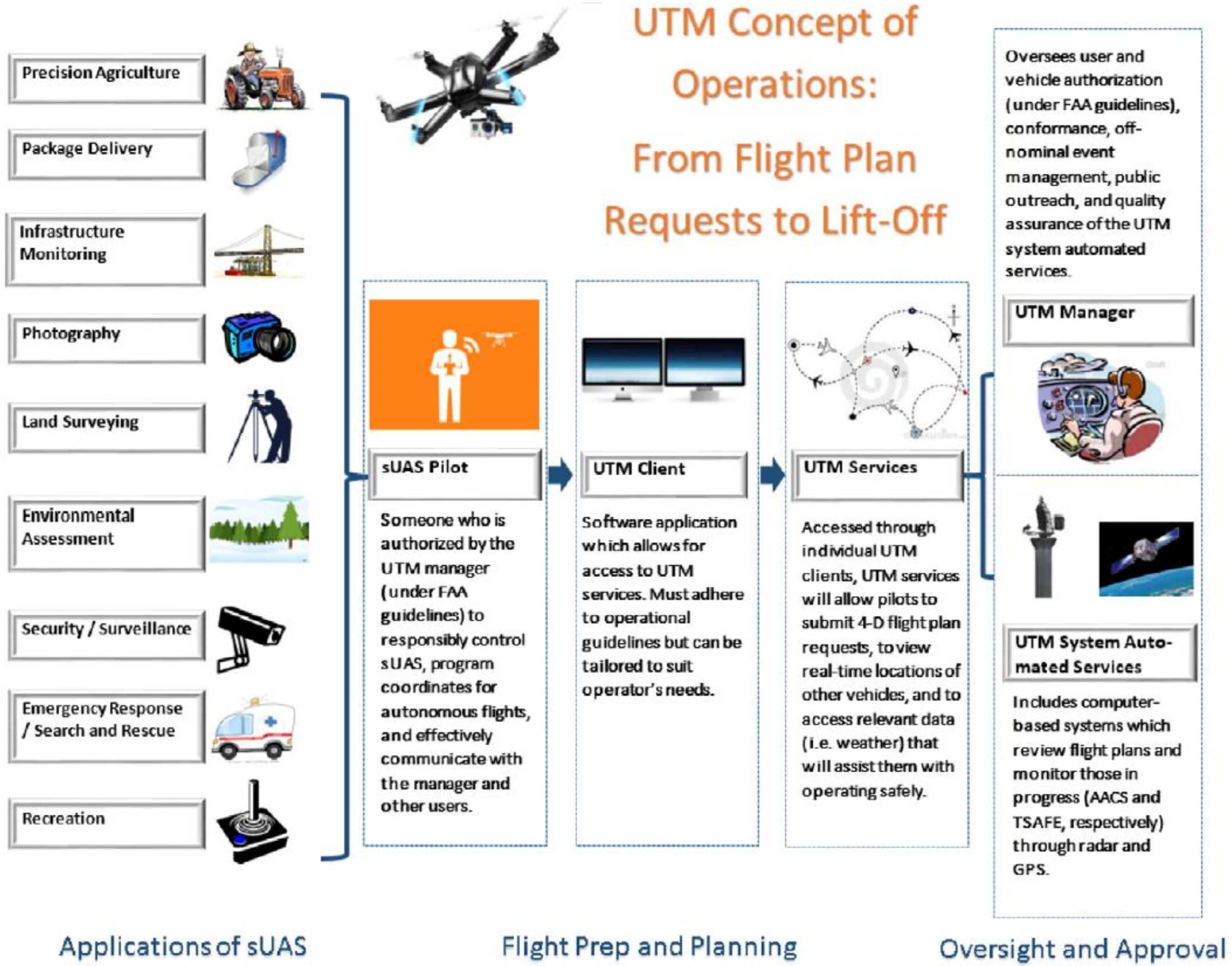


Fig. 5G Cellular-Connected Devices

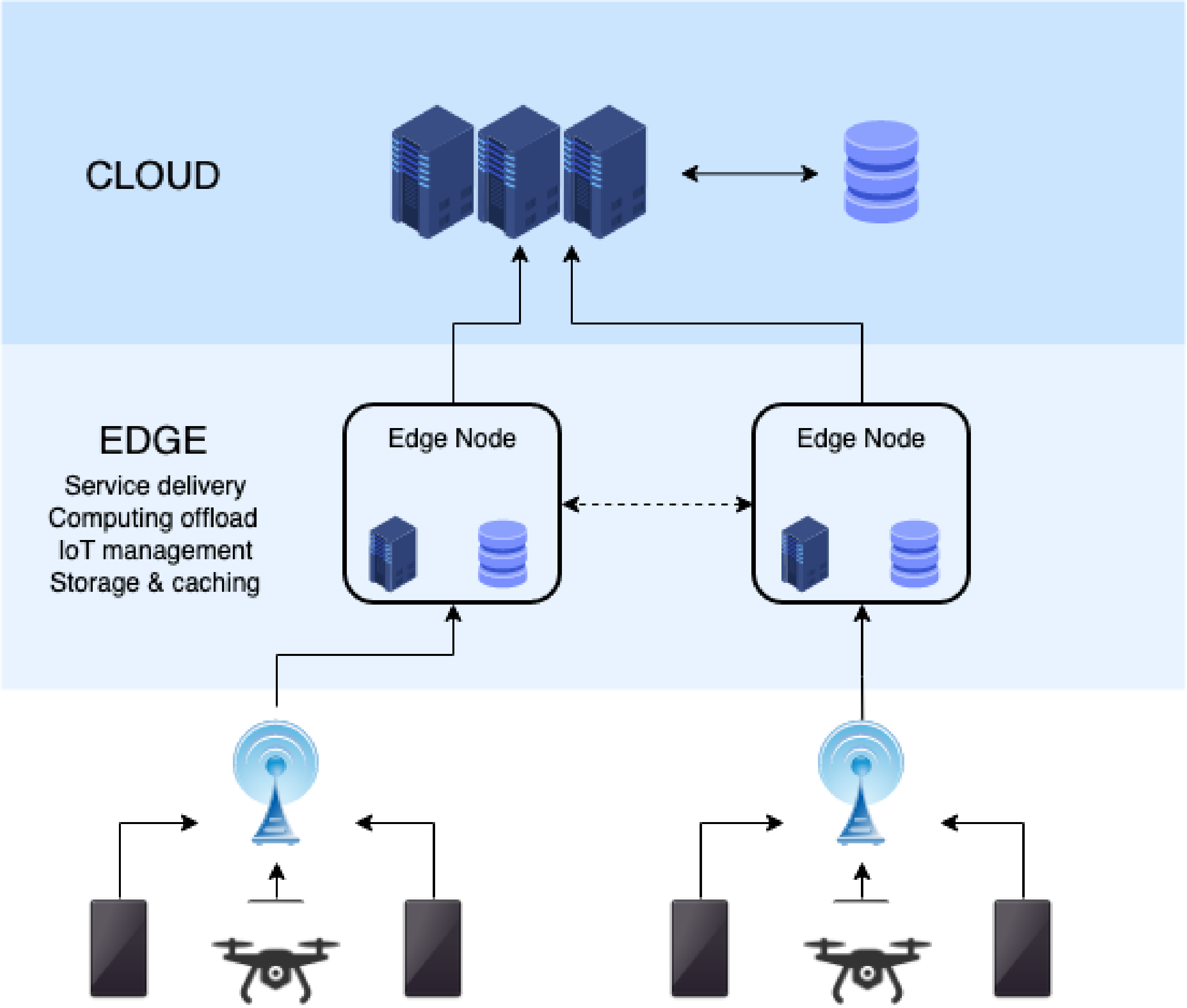
UAV Traffic Management (UTM)

- The figure is an UTM system concept of operations flow chart.



Multi-Access Edge Computing (MEC)

- MEC push cloud-like services to the network edges.
- This will reduce the latency and increase the reliability of the communication.



EXPERIMENT

Experimentation Introduction

- The management of UAVs' traffic is mainly based on the dynamic definition of aerial geo-fences to specify the allowed and the restricted flight zones.

- The UTM controls the flight plan of each UAV to ensure that it is flying inside an allowed geo-fences.

- We had known that latency and packet loss will damage the reliability of communication, so we leverage this experimentation to test the impact of the two situations.

What's the impact of

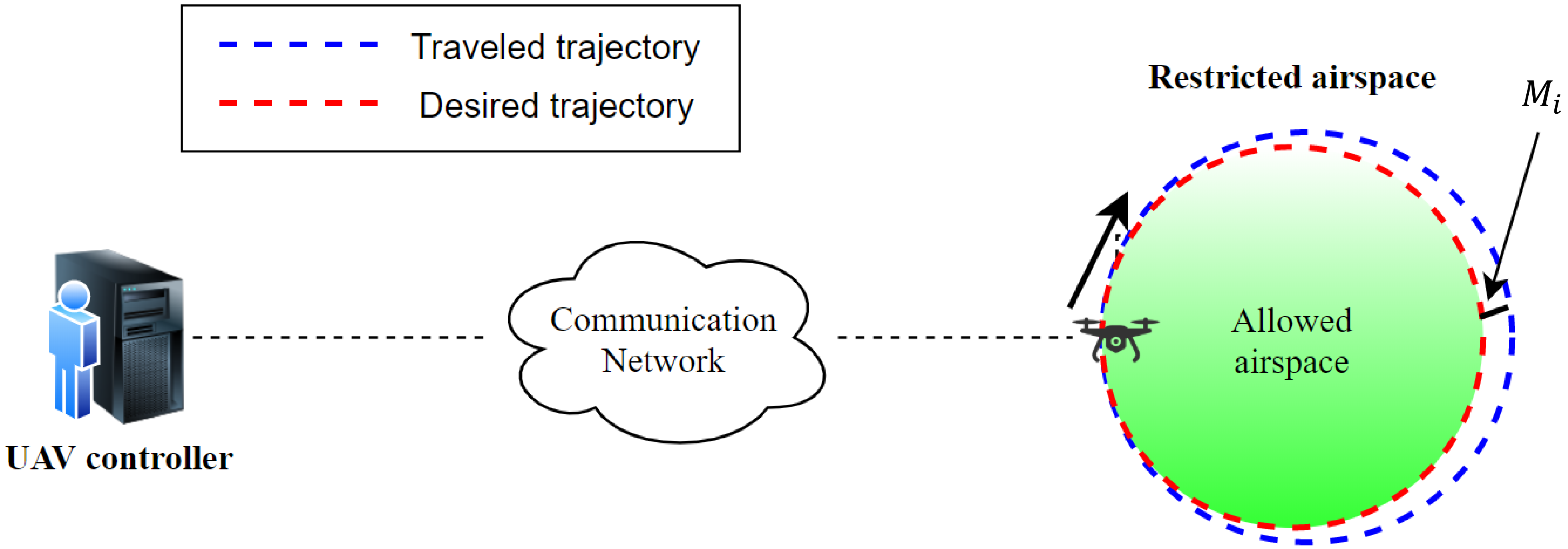
Latency ?

Packet Loss ?

Experimentation Methodology

- In order to investigate the impact of latency and packet loss to UAV control, the authors find a most challenging case.

- The authors configure the following experimental scene. They want to keep the UAV flying on the border without crossing.



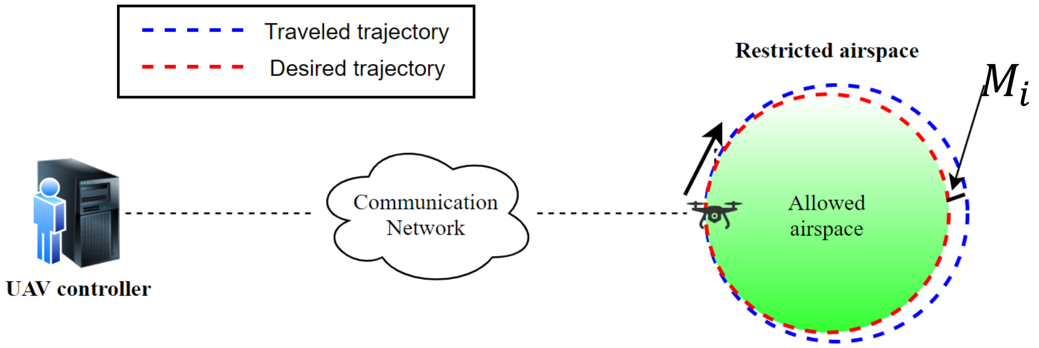
Experimentation Methodology

- Then we will measure two arguments to evaluate flying stability.

1. The average of crossing distances C_{avg}

$$C_{avg} = \frac{\sum_{i=1}^{Nb_m} M_i}{Nb_m}$$; M_i is the distance between UAV and border, Nb_m

2. The deviation ratio D_r



$$D_r = \frac{O_D \times 100}{T_D};$$

O_D is the distance traveled outside the allowed geo-fence.

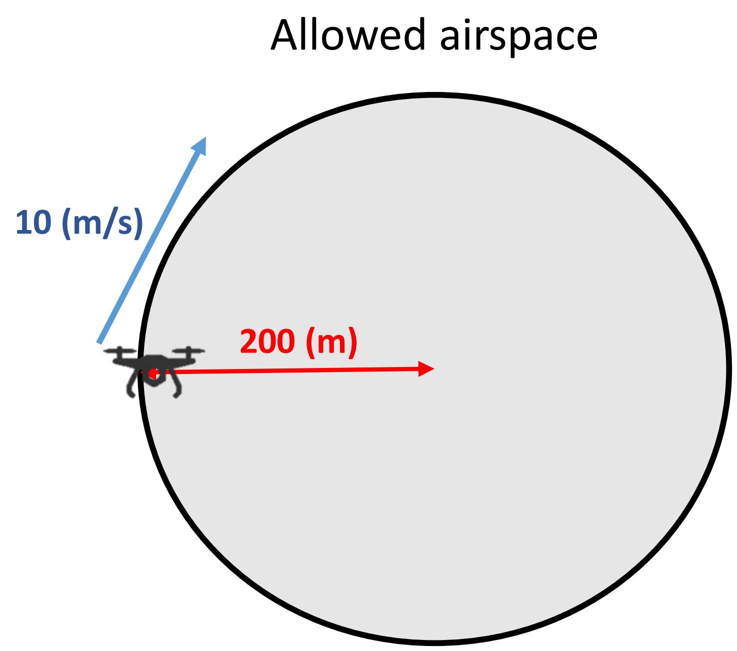
T_D is the total traveled distance.

Experimentation Setup

EXPERIMENT TOOL	
UAV Controller (First VM)	UAV Controller is developed using the Python drone-kit API which is an implementation of the MAVLink protocol, used for the communication with drones.
Network (Second VM)	Through network emulator to simulate the communication between UAV Controller and UAV with latency and packet loss.
UAV operation (Third VM)	Using Software-In-the-Loop (SITL) emulator that allows running the open-source UAVs' autopilot ArduCopter with the same behavior of a real UAV.

Experimentation Setup

- The important configuration of UAV Controller.



Flying duration : 300 (s)

Frequency : 100 (Hz)

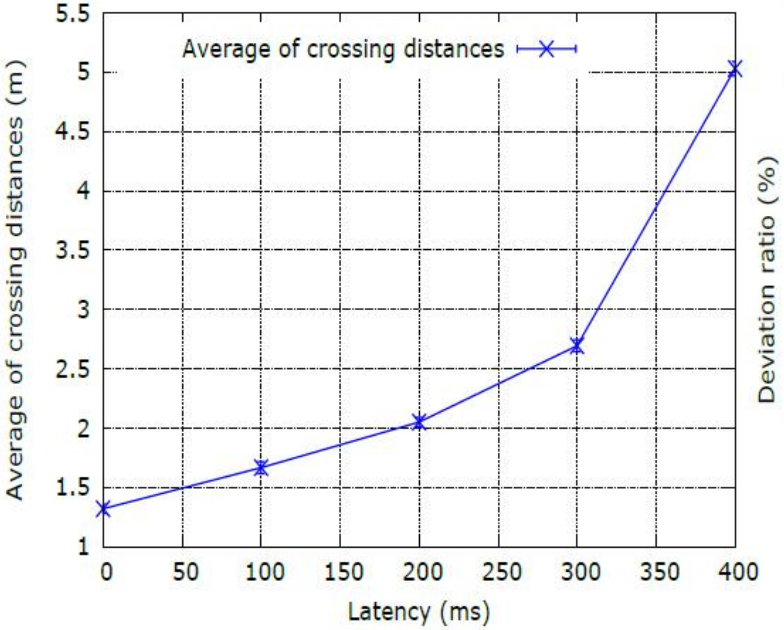
Check the states of UAV and correct deviation every $\frac{1}{100} = 0.01(s) = 10(ms)$

Result & Discussion

- The following figure elaborate the effect of **latency** to UAV.

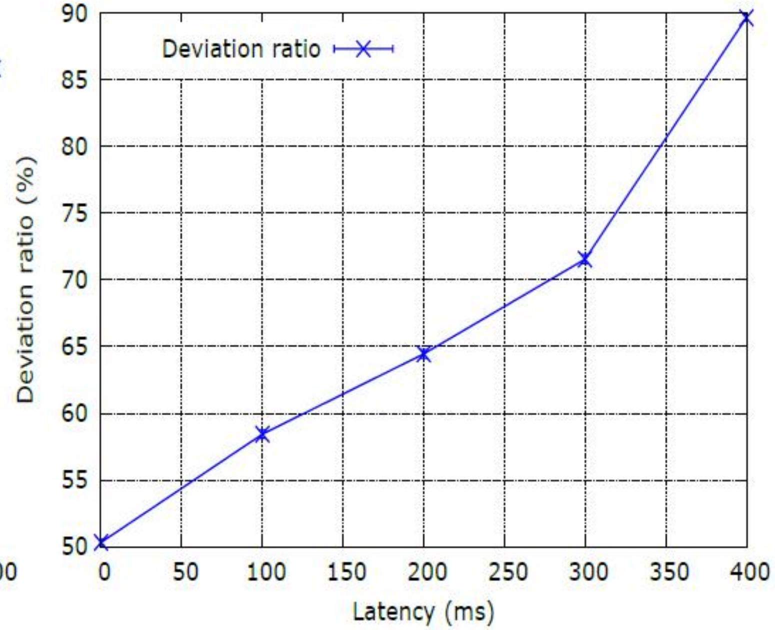
(a) Desired (red) vs Traveled (yellow) trajectory in presence of high latency.

$$C_{avg} = \frac{\sum_{i=1}^{Nb_m} M_i}{Nb_m}$$



(b) Average of crossing distances.

$$D_r = \frac{O_D \times 100}{T_D}$$



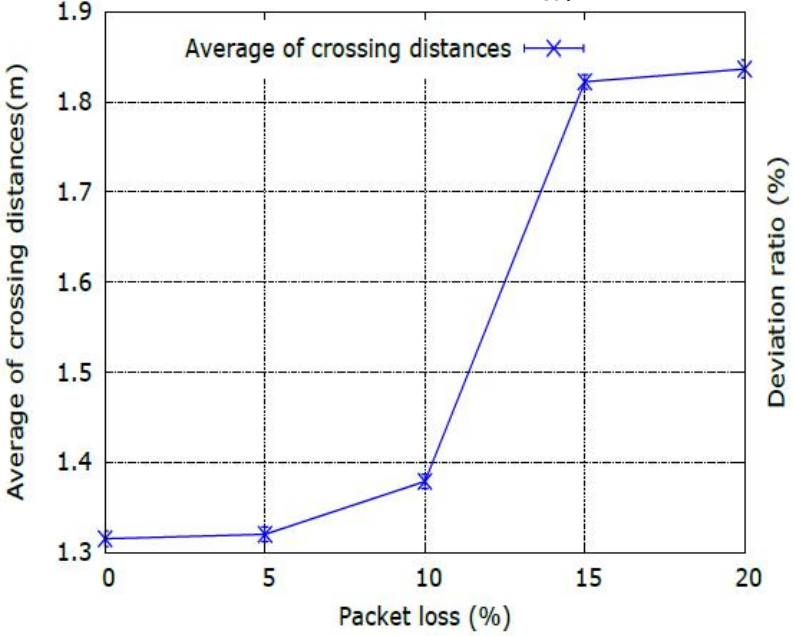
(c) Deviation ratio.

Result & Discussion

- The following figure elaborate the effect of **packet loss** to UAV.

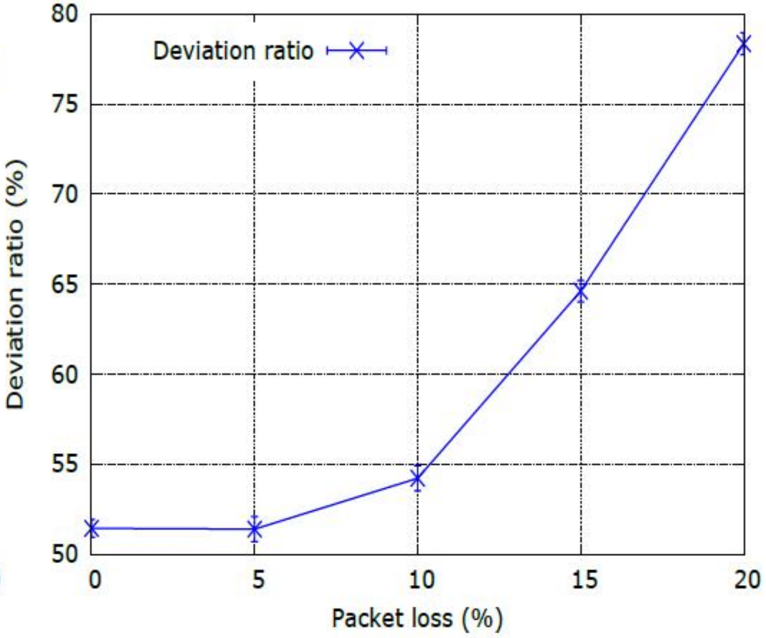
(a) Desired (red) vs Traveled (yellow) trajectory in presence of Packet loss.

$$C_{avg} = \frac{\sum_{i=1}^{Nb_m} M_i}{Nb_m}$$



(b) Average of crossing distances.

$$D_r = \frac{O_D \times 100}{T_D}$$



(c) Deviation ratio.

Result & Discussion

- In this experiments, the authors measured the exact averages of crossing distances and the deviation ratios for different values of network latency and packet loss.

- When latency or packet loss rate increase, the averages of crossing distances and the deviation will increase as well.

- On the other hand, this experimentation would help to choose the placement of the remote UAV controller according to the tolerated deviation.

METHOD

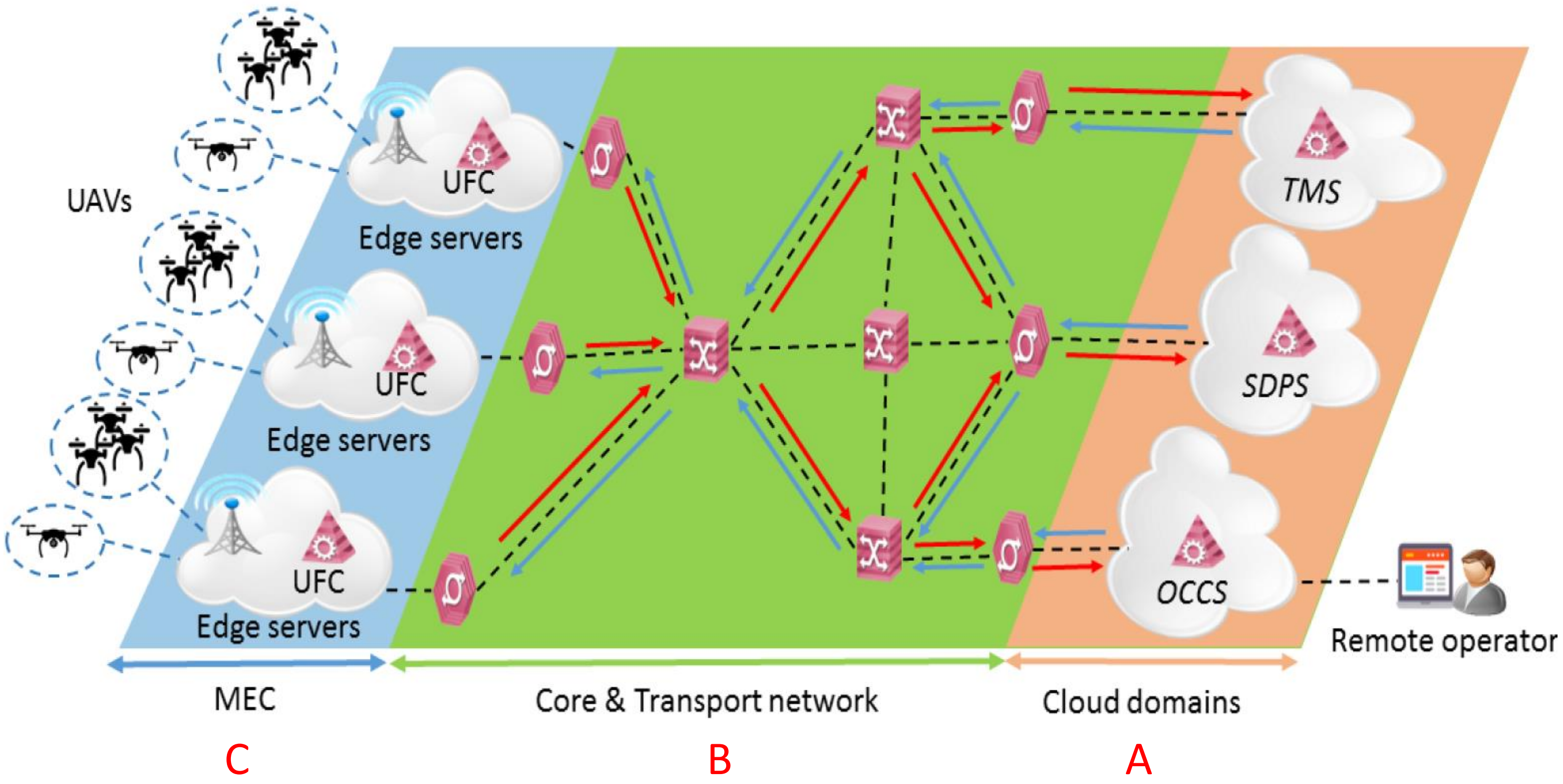
MEC-Based UAVs' Traffic Management Framework

- Based on the aforementioned results, the latency and packet loss have a dramatical impact on the control of the UAVs' flights.

- For this reason, the authors propose a new framework that leverages MEC for ensuring that the UAVs stay within their defined geo-fences as much as possible.

MEC-Based UAVs' Traffic Management Framework

- The following figure is the architecture of the proposed framework of this paper.



- The proposed framework can be divided into three parts (A, B, C).

MEC-Based UAVs' Traffic Management Framework

- The proposed framework can be divided into three parts (A, B, C).

A. Cloud Domain :

The cloud domain hosts all the management services. Here, three principal services can be identified.

- **UAVs Traffic Management Service (UTMS) :**
  UTMS has all the information such as UAVs' location, flight plan and airspace restriction. Also, this service is responsible for defining geo-fences.

- **Supplementary Data Provider Service (SDPS) :**
  SDPS provides some useful information for planning UAVs' flights such as weather forecast and location of interest.

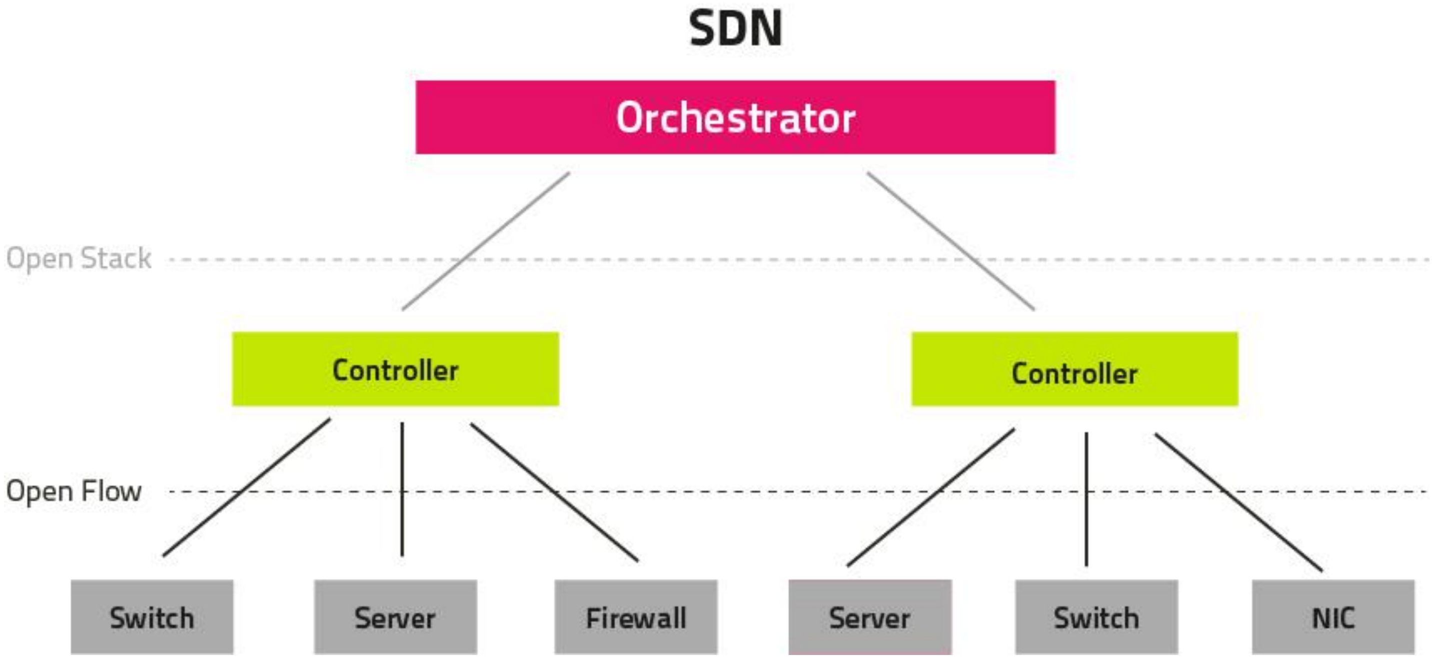
- **Operator Command and Control Service (OCCS) :**
  OCCS provides an interface for the remote operators to monitor and interact with UAVs in real time.

MEC-Based UAVs' Traffic Management Framework

B. Core and transport network :

The core and transport networks ensure the transmission of communication traffic between MEC-hosted services and the previous Cloud-hosted services. Given that this communication belongs to ultra-reliable and low-latency Communication, the generated traffic must be treated with a high QoS. In this proposed framework, the core and transport networks are considered to be SDN-enabled networks.

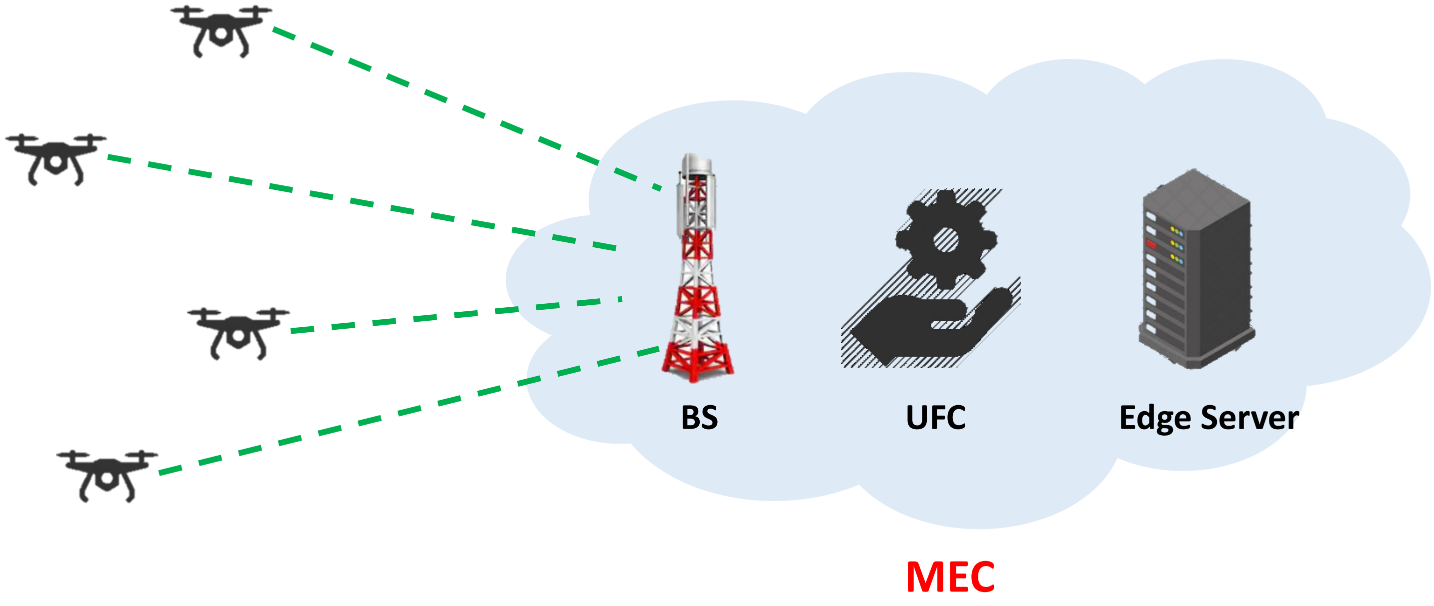
SDN can be used to ensure a flexible QoS provisioning.



MEC-Based UAVs' Traffic Management Framework

C. Mobile edge computing :

In this framework, MEC nodes are used to host UAVs Flight Controller service (UFC). The UFC is responsible for the monitoring and controlling the UAVs that connected to MEC nodes. Also, UFC collects information (i.e., geo-fences, weather forecasts and location of interest) and command from cloud-hosted services, and accordingly adapts UAVs' flights.



Experimentation Tools and Parameters

- The edge server used in this testbed. It's Intel Fog Reference Design.

- The experimentation parameters.

Parameter	Description	Values
CPU cores	The number of physical CPU cores in the edge server.	4
RAM	Available RAM in the edge server.	32 GB
Throughput	Available throughput for the communication between the edge server and the UAVs.	100 Mbps
UAVs number	The number of UAVs connected to edge.	20, 40, 60, 80, 100
Speed	The speed of the UAVs	10 m/s
Duration	The duration of the flights and the simulations.	300 s
Radius	The radius of the allowed geo-fence.	200 m

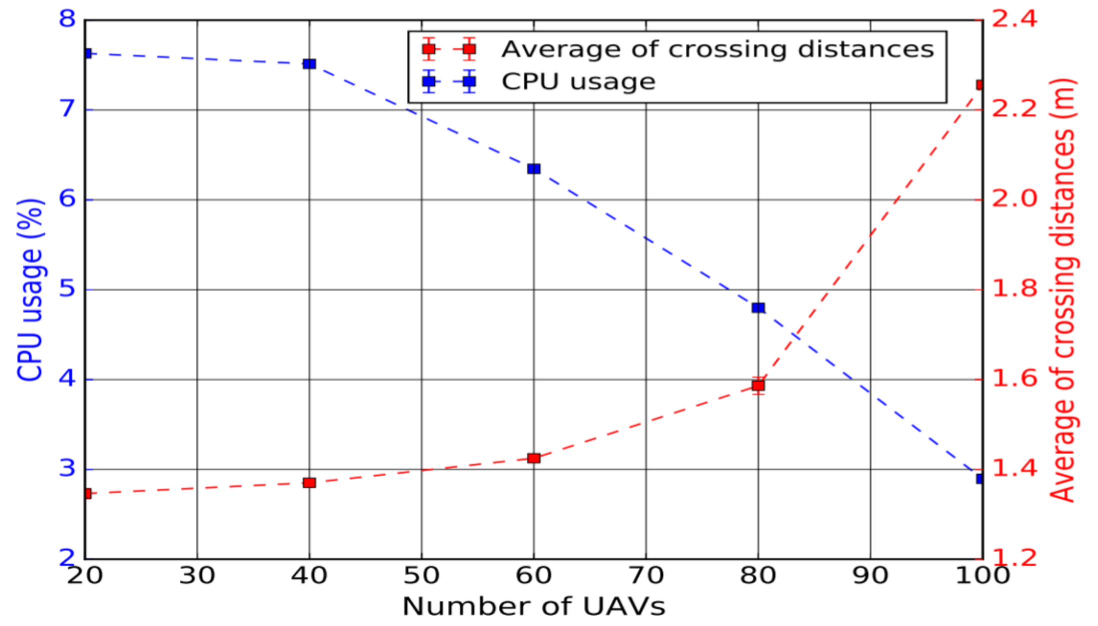
Experimentation Results

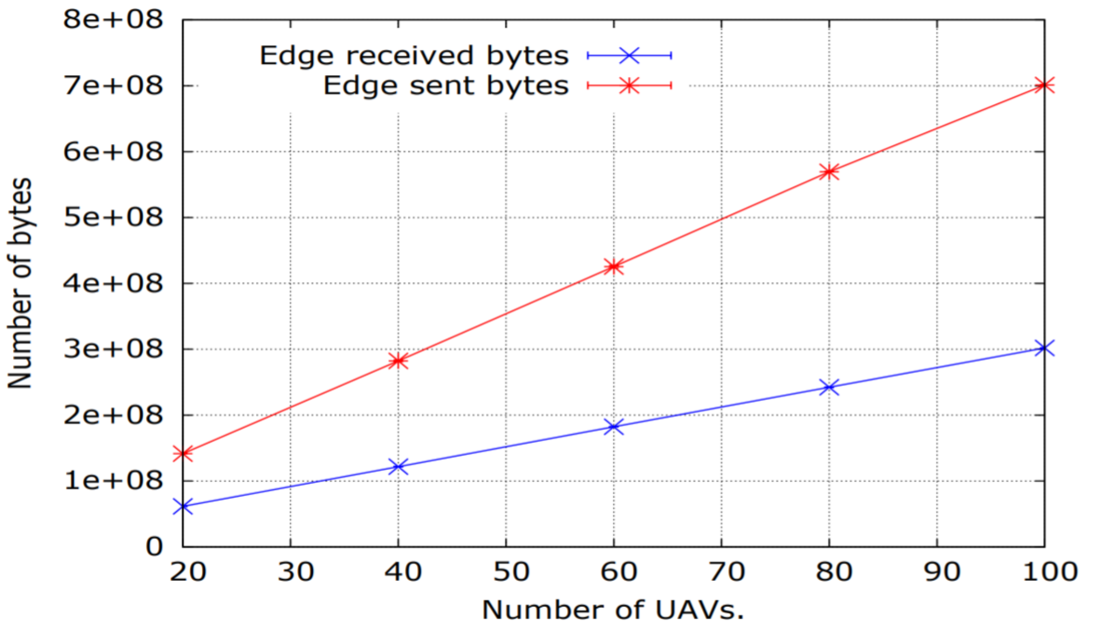
- Communication latency and packet loss would approach to 0.

- The first figure shows the CPU percentage and allocated to a control agent versus the average of the C_{avg} values of the set of UAVs connected to edge server.

- The second figure illustrates the evolution of the traffic exchanged between the edge servers and the connected UAVs as a function of the number of UAVs.

During the experimentation, each UAV produced **3028Kb** of traffic, which corresponds to a rate of **10Kbps** ; each UAV received **7152Kb** of traffic, which corresponds to a rate of **24Kbps**.





DISCUSSION

Conclusion

Air Traffic Management System

UAV Traffic Management System

UAV Traffic Management System with Multi-Access Edge Computing

Proposed framework

Along with the ever-increasing number of UAVs, the on-site control of UAVs, by pilot within VLOS, is becoming all but impossible.

In general UTM system, communication latency and packet loss always have negative effect in controlling UAVs.

System Comparison

	Air Traffic Management	UAV Traffic Management	UAV Traffic Management (MEC)
Application	That's not designed to handle high density of UAVs' traffic.	That's designed to handle high density of UAVs' traffic without high reliability.	That's designed to handle high density of UAVs' traffic with high reliability.
Latency and packet loss	With higher latency and packet loss.	With higher latency and packet loss.	Latency and packet loss would approach 0.
Cost	High (Labor cost)	Low	High (Deploy edge node)
Scope of application	Low	Middle	High

Q & A

Thank you for your attention