[EN-I-084] Traffic Management of Unmanned Aircraft Systems (TM-UAS) in Urban Environment

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Abstract: A high-level framework on how large scale UAS operations can be managed, particularly in the urban environment is presented in this paper. The urban environment presents unique challenges to UA operations, such as C2 link coverage loss due to reflections from the buildings, risks to other users sharing the same urban airspace, as well as restrictive maneuverability within limited airspace over urban infrastructures. The paper also discusses how the urban airspace could be structured based on the performance of the airspace. The concept of dividing the airspace into airblocks, which depicts the performance of the airspace within the area, will be introduced to visualize the recommended flight paths. The UA operator and UTM Operator will then be able to identify the safe and efficient flight path for each mission. The key concepts and considerations in managing the urban airspace will also be discussed, while the current state of art of the NTU ATMRI's TM-UAS programme will also be demonstrated in the presentation.

Keywords: Traffic Management of Unmanned Aircraft Systems, Urban Airspace, Unmanned Aircraft

1. INTRODUCTION

Unmanned Aircraft (UA) or commonly known as drones are known to be potentially deployed for many use cases, for example last mile deliveries [1] and surveillance [2]. Given that there are more than half of the world population currently staying in urban areas [3], it is anticipated that the global UA market will grow at CAGR of 9.83% [4]. The deployment of UA for operations that are classified as Dull, Dirty and Dangerous are becoming increasing popular and have been adapted by government agencies. More so, there is a lack in studies in structuring the urban airspace so as to achieve optimization of urban airspace which is finite. Given the anticipated increase in the use of UA, it becomes increasingly critical to develop a robust and rigorous traffic management framework to enable UA operations within the urban environment.

Currently, agencies such as National Aeronautics and Space Administration (NASA) [5] of United States of America and Netherlands Aerospace Centre (NLR) [6] are currently looking into developing the concepts of operations of traffic management of UA, however, there is lack of research that studies the traffic management of UA for urban environment. The study includes but not limited to establishing the urban topography and its influence on the operations of UA. For instance, a key consideration would be the Command and Control (C2) link between the UA and the operator, since the uplink and downlink will be affected by the presence of the urban infrastructures within the environment. Other factors include risks to the other urban users, such as the risk of injury to the other urban users during a potential failure of UA, the effects of urban infrastructure on the dynamics of the UA and the operation of UA within the GPS-denied environment due to buildings.

This paper aims to introduce the high-level framework, known as urban Traffic Management of UA Systems (uTM-UAS), and to introduce the key modules and functionalities of within this framework, as well as the key considerations into the development of the framework.

2. ATMRI TM-UAS PROGRAMME'S APPROACH

In the traffic management of the UA operations in the urban airspace, a different paradigm from the manned aviation is required. The current air traffic management (ATM) in the manned aviation is one that is regulated,

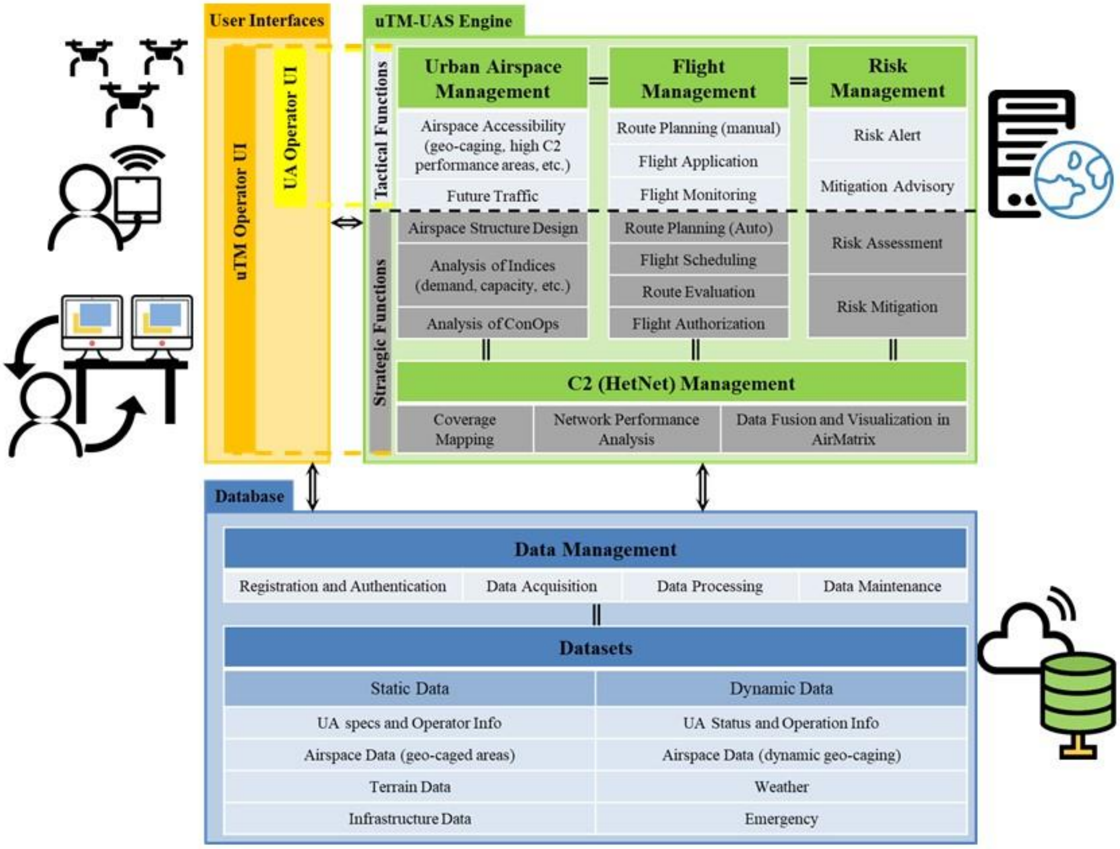

Figure 1 Schematics of the uTM-UAS framework

therefore any potential technological and procedural advances will take a significant time to be implemented. This is, however, necessary as any potential incidents will escalate to become one that is catastrophic, hence the traffic management of UA have to be extremely structured and rigid to minimize the possible incidents that might take place otherwise. In comparison, one may anticipate that the potential disaster that arises from UA operations to be less catastrophic, therefore the required mitigation actions may be of a lesser extent compared to manned aviation. Furthermore, from a practicality point of view, additional redundancy measures onboard will pose additional payload challenges to the aircraft and this will heavily limit the efficiency and hence the potential business case for UA operations.

Given that traffic management of UA within the urban environment is a relatively new area of studies, there are currently limited standardization or rigid systems in place, this will then allow any potential proposals to be considered and implemented easily. As such, one may consider a framework that incorporate both safety and efficiency management of UA operations as the key philosophy. As such, the key mantras for traffic management of UAS in the urban environment may be summarized as follows [7]:

1. The urban airspace will be managed flexibly, with constraints imposed only when necessary.
2. The airspace shall be managed dynamically, with the airspace performance assessed in real time continuously.
3. Only UA having performance specifications meeting the performance of urban airspace will be allowed to operate within the airspace
4. Safe & Efficient Operations

With these key mantras, the uTM-UAS framework was developed.

3. OVERVIEW OF THE uTM-UAS FRAMEWORK

In the design of the framework for uTM-UAS, one key motivation is that the system has to be user-centric, taking into account of the needs of the UA operators, UTM operators, as well as other stakeholders such as regulators and service providers. Furthermore, the framework should include functionalities to perform strategic planning and tactical operation. This will enable pre-assessment of airspace performance, optimal airspace structure based on demand and capacity, and risk management prior to tactical operations where real-time updates will be fed into the uTM-UAS system for real-time analysis. The uTM-UAS framework consists of several key modules that are integrated into each other, namely: the Database, uTM-UAS Functions and the User Interfaces, as depicted in Fig. 1.

3.1 Database

The Database manages both the static data, such as UA specifications, permanent no-fly zones and terrain information; as well as dynamic data, such as real-time UA operating status, weather and dynamic geofencing of the urban airspace. The database serves as the "circulatory system" for the framework, where information will be relayed to all modules and made accessible appropriately to UA operators, UTM operators, as well as to be integrated into the core uTM-UAS functions for strategic and tactical decision making.

3.2 uTM-UAS Functions

The second aspect of the framework is the core function, which can be broken into 4 main modules:

1. Urban Airspace Management
2. Flight Management
3. Risk Management
4. C2 (HetNet) Management

A challenge that is particularly different for UA as compared to manned aviation is the lack of on board pilot, therefore maintaining ubiquitous C2 coverage between the UA operator and the UA becomes extremely important for safe and efficient operations. The TM-UAS programme is currently looking into using Heterogeneous Network (HetNet) as a means to sustain C2 coverage for large scale UA operations. As a result, the C2 management module serves to assess the HetNet performance within the urban airspace and could the trajectory of each mission be supported safely. The information derived from the C2 management module is passed back to the Database for further evaluation by other modules.

The Urban Airspace Management module will then compute the appropriate structure for UA operations. In addition, the different airspace indices, such as demand and capacity, will be analyzed within the module and the urban airspace management will account for different ConOps requirements.

The Flight Management module will plan, schedule the routes, and authorize the UA operators' flights based on the inputs from the Urban Airspace Management module. It also provides for the real-time flight monitoring.

The Risk Management module identifies and quantifies the dynamic risks of operations for each mission based on the database data for each phase of flight. It then provides risk assessment and mitigation evaluation during the strategic phase, while also providing for the risk alert and advisory in real-time.

3.3 User Interfaces

The last component of the framework is the User Interfaces. Within the framework, the UA and UTM operators will have unique users' interfaces, this will ensure that only the relevant information will be passed on to the UA and UTM operators.

4. AIRMATRIX AS VISUALIZATION OF AIRSPACE PERFORMANCE

One of the modules in the uTM-UAS Framework includes the assessment of airspace performance depicted by AirMatrix, as shown in Fig. 2. AirMatrix is a means to assess the performance of urban airspace. A key feature of the AirMatrix is that the size of each airblock may be dynamically configured based on the types of missions, UA size and performance. For each airblock, they may be color coded based on the performance, which will be further elaborated below.

In the computation of the airspace performance for each airblock, some of the factors that may be considered are as follows:

- Presence of infrastructures around airblocks
- Presence of geofenced and geocaged areas
- Quality of C2 coverage
- UA size and performance

These factors will be quantified as an overall index derived to give the overall airspace performance for each airblock. With the color code based on the airspace performance, both the UTM and UA operators will be able to clearly visualize the airspace and regions where flights are permissible, without the need to overload themselves with the manual assessment for a safe mission. For instance, by incorporating the urban topography, i.e. the presence of buildings and infrastructures, into the computation of the airspace performance, the operators will now be able to derive the possible flight paths that are sufficiently far (well-clear) from the infrastructures. The UA operators can then use this information to gain a better situation awareness of the airspace and make better decisions with respect to their operations.

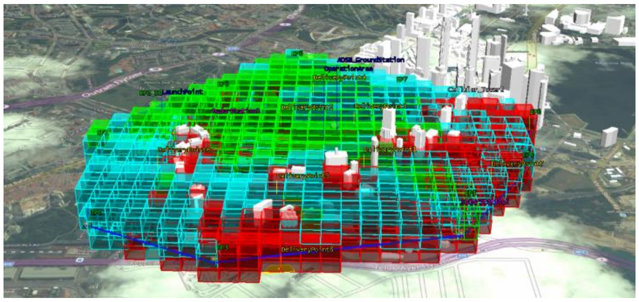

Figure 2 Visualization of the AirMatrix over an urban area

With the AirMatrix, one can establish the safe flight path for each UA during each phase of flight. For UA, the following phases of flight have been identified:

1. Take-off
2. Climb
3. Turn
4. Hover
5. Cruise
6. Descent
7. Land and engine-off

With these phases of flight, the UA operators and/or UTM operators may now map out the possible safe flight path for each phases, as shown in Fig. 3.

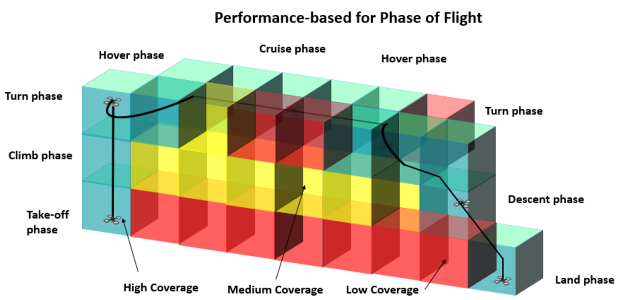

Figure 3 Sample schematics of safe flight path based on phases of flight

5. CONCLUDING REMARKS AND FUTURE WORKS

In this work, a high level overview of the framework for uTM-UAS is presented with the aim to manage the UAS operations in urban airspace.

As part of the continuous effort to enable the large scale UA operations within urban airspace, ATMRI is currently undertaking work in the following areas:

1. Establishing the C2 coverage and quality within the urban environment through simulations and field testing
2. Development of the uTM-UAS prototype based on the framework
3. Study of the associated technologies, such as geofencing and detect-and-avoid (DAA)

In the near future, ATMRI will be setting up field testings to evaluate the concepts of operations modelled and simulated within the simulation and modeling tool.

As the area of research of traffic management of UA is a rapidly growing field, the work presented is also an evolving document, where the details of each concept will evolve with new developments in technology and requirements. However, it is also believed that the framework presented in Fig. 1 depicts the main functionalities that any UA framework should have, in order to ensure a safe and efficient management of large scale multi-mode UA operations within the urban airspace.

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