[EN-I-006] The MoNIfly approach to an Unmanned Traffic Management System (UTM)

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+B. Blom *, T. Feuerle *

* TU Braunschweig, Institute of Flight Guidance
Hermann-Blenk-Str. 27,
38108 Braunschweig, Germany
[b.blom |t.feuerle]@tu-braunschweig.de

Abstract:

This paper presents the MoNIfly project, an EU funded research project to investigate a low-level Unmanned Traffic Management system. With the use of the Mobile Network Infrastructure, MoNIfly is contributing to a safe and socially acceptable integration of remotely piloted aircraft systems into existing airspace and urban areas. Geo-fences and infrastructure to vehicle communications will be used in the project.

Keywords: Unmanned Traffic Management System (UTM), mobile network infrastructure, Remotely Piloted Aircraft System (RPAS), UAS

1. INTRODUCTION

The number of drones in commercial and recreational use is expected to grow significantly within the next years. Currently the most dynamic market is in low flying remotely piloted and autonomous aerial vehicles. In 2016 the European Aviation Safety Agency (EASA) has published three different categories of such drones: an open category, a specific category and a certified category. The vehicles are differentiated by the risk associated to their operation, granting operators access to the airspace with a flexible approach to authorization of the operations. The MoNIfly project (Mobile-Network Infrastructure for Cooperative Surveillance of Low Flying Drones, funded under European Commission HORIZON2020 framework program) targets the open and specific categories by proposing a drone traffic management system based on mobile network infrastructure.

One of the core challenges related to making use of drones in urban environments will be the acceptance of low flying devices by the general public, as drones produce noise, can fly directly and low above private territory and usually carry cameras and other sensors, causing arguments about safety, privacy and regulatory issues. Therefore innovative solutions must be found, developed and demonstrated to allow safe and society friendly as well as aviation-harmonized drone operations. The MoNIfly concept will enable applications with virtual barriers (so-called geo fence applications) that use static restrictions as well as object- or time-defined barriers with high-dynamic update rates to support moving vehicles. This means that the risk of collisions of drones with static obstacles but also other drones or aircraft/helicopters will be greatly reduced. Additionally this concept will allow protection of privacy sensitive areas like private houses/gardens or even scenes of an accident or incident. The proof of concept will be demonstrated and validated in a test campaign. This campaign will take place on a former military airfield in the Netherlands, which is now open for public usage. In this environment the interfaces and interoperability aspects of low flying drones and other air traffic will be investigated. The suitability of using the mobile network infrastructure for this purpose will also be investigated.

The paper and presentation will cover the MoNIfly concept; it will describe the main hardware components which will be developed to assure a secure and highly reliable communication of the low flying drones with the mobile network infrastructure and its interfaces to the overall Air Traffic Management system. The paper will also discuss the planned validation.

2. THE MONIFLY CHALLENGE

MoNIfly proposes an innovative concept for enabling cooperative surveillance and air traffic management in low altitude airspace. With this concept, future operations of drones will be conducted safely through the use of established mobile phone network infrastructure. The project will provide a detailed analysis of the applicability of mobile network infrastructure to low altitude aerial applications in general and to the traffic management of drones in particular. For this, the performance characteristics of forecasted commercial drone applications will be analysed and related to the low altitude traffic environment. The joint understanding of drone mission profiles, forecast traffic and cellular network performance will be used to establish a concept for a low altitude air traffic management system, initially focused on the management of drones. It is expected that for the forecasted traffic levels in low altitude airspace to operate seamlessly and reliably, a traffic management system along the lines of traditional Air Traffic Management and Air Traffic Control systems, but with vastly different characteristics, is required. The MoNIfly system contributes towards conflict prevention using bi-directionally transmitted information for surveillance, communication and control of drones. For data exchange, the established cellular network infrastructure is used and conceptually enhanced as required to enable positioning and communication between drones and involved air traffic management entities. Building on that, MoNIfly aims at combining the support system with dynamic geo-fencing applications which are not limited to static objects but can be applied to moving targets such as manned air traffic or other drones. Through this, MoNIfly intends to address the issue of society acceptance of drones as well as introduce a method of airspace conflict mitigation.

Conflict mitigation will rely on recommendations given to the operator of a drone, but options to guide the drone out of the respective zone are to be examined within MoNIfly.

As primary objective of MoNIfly the established concept will finally be validated in detail on a prototype level by operating manned traffic in direct vicinity of various drones. As a safety precaution, it is expected that the operations take place in different altitudes, pretending to happen in closer proximity than possible due to safety reasons. Interactions between manned and unmanned traffic can be investigated as well as interactions between different drones. The results of the project will lead towards a proposal for common technology to be implemented into future drones for safe and simplified cooperative use. As a secondary objective, this project will provide input to rule makers by deriving requirements which new regulations can be based upon using results from the operational validation.

The overall relevance of this subject can be seen through increasing media reports on drone conflicts, market growth and novel drone technologies presented at conventions but also through the ongoing discussion of required regulatory changes. Additionally, discussions on the ethics of using drones with respect to possible privacy infringements are emerging. With applications like delivery services by drone in metropolitan areas being investigated and developed and first commercial applications already in place, it is expected to be a matter of time until the number of drones in metropolitan areas will skyrocket. This will likely raise privacy, security and safety concerns.

An extract of the project goals are:

- Qualify LTE modem for communication between RPAS and UTM
- Qualify drone to equip LTE modem
- Validate Unmanned Traffic Management (UTM) in relevant environment (mixed traffic, LTE network coverage)
- Demonstrate usefulness and usability of MoNIfly approach for drone-2-infrastructure communication and monitoring

3. THE MONIFLY APPROACH

The concept proposes the integration of commercially operated drones as well as non-commercially operated unmanned vehicles in lower airspace utilizing specially tailored mobile phone network connections. For this it is assumed that each drone is required by regulation to carry a specified datalink module on board which establishes connection with the available cellular mobile network infrastructure (comparable to cellular log-on of mobile phones). Before take-off and during operation in the shared airspace, the drone has to send its current position and other relevant information, for example mission intent, to a shared traffic surveillance and control system. The system will provide the drone as well as the operator with information on any relevant static and dynamic geo-fenced areas, enhancing the situational awareness of the operator. Additionally, the system will determine the actual position of all connected drones within the area covered by available network cells by means of multilateration (MLAT), signal to noise ratio (S/N0) measurements or comparable techniques. This provides an additional safety layer of redundancy due to position information being available from multiple independent sources. It also allows including the position of vehicles equipped with simple cellular network datalink into the traffic management concept which do not possess independent navigation or positioning capabilities. The general MoNIfly concept is depicted in Figure **1**.

In addition to pre-defined static geo-fenced zones, dynamic geo-fencing areas can be established which only exist temporarily and can be applied to geographical areas but also to moving vehicles. These geo-fenced areas will be used for detection of conflicts between drones and other geo-fencing areas but also between individual drones, allowing the system to suggest evasive actions to keep a drone clear of any conflict. Different areas can further be prioritized to attribute right of way to priority traffic (e.g. rescue services).

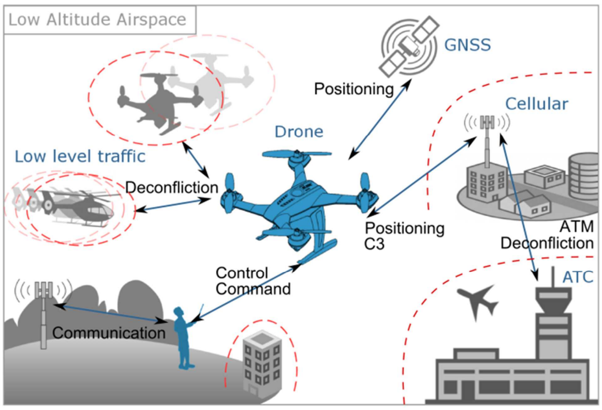

Figure 1: General MoNIfly concept depiction

Another application of dynamic geo-fences is seen in the application of temporary no-fly zones by competent authorities (police, fire brigades, first-line-responders). For example, during an accident, the authorities are able to create a no-fly-zone within seconds. For the duration of rescue operations, no regular vehicles are permitted within these zones, creating a safe zone to conduct all required operations and possibly use future rescue drones without disturbances.

Although the project primarily targets drone operations, especially the investigation on the use of cellular infrastructure for ATM and positioning services can be considered trans-disciplinary. The ATM part can be applied to information sharing and data exchange of other operations with reception of cellular signals, including ground based vehicles. Positioning services likewise can be applied to any operation within range of cellular signals, including regular uses such as smartphones.

Throughout the project, field test demonstration within realistic but likely restricted areas will evaluate the feasibility of the taken approach and will serve as validation. As such the project aims for results at a TRL-4 to TRL-5 scale with the expectation that the technology will be able to reach TRL-6 by mid-2030 due to expected increasing efforts in the domain of low altitude drone operations.

The technical opinion published by EASA reflects the approach taken by MoNIfly, stating that the increasing demand of urban drone operation will require cooperation with other airspace users and likely also a method of low altitude traffic management [1]. Also the use of geo-restricted zones is mentioned as necessary measure to cope with the future developments. These efforts are listed as required research for future implementation and refinement of the regulations currently in development. This shows the applicability of this project to recent developments in regulatory frameworks.

A drone operator interface has been developed at TUBS for small drones in low altitude operations. It allows parallel monitoring and management of multiple RPAS of different types in scientific and industrial environments. With this interface, static definitions of Geo-fences, 3D flight corridors, no-Fly zones and safety landing spots are possible. The interface monitors the drone's state via live telemetry and reacts if e.g. a drone violates procedures or airspaces.

Within MoNIfly, this interface will be used to develop and implement Dynamic Airspace Allocation (DAA). DAA defines temporal valid airspaces with dynamic extent and different categories. For example No-Fly-zones (NFZ) which are bound to manned rescue or police helicopters and therefore forbid RPAS flying into these zones, advising operators on exit strategies or even guide the drone out of the area. Another category of airspace could be defined in urban areas and near to sensible infrastructure such as power plants, where RPAS are only allowed to fly if they are equipped with minimum required transponders and datalinks (analog to TMZs in conventional aviation) or special permissions.

In case of an imminent airspace violation of Dynamic Airspace Allocation, the operator will be provided with cues on how to resolve the current situation. Once the airspace violation occurred, high level commands will be used to override any other autopilot operations. Therefore, a datalink and a high-level-command protocol have to be defined and implemented. Because this is a highly sensitive topic, the MoNIfly environment will in future serve as testbed to validate different approaches to overriding user input and making the transition between user and automatic control transparent to the user.

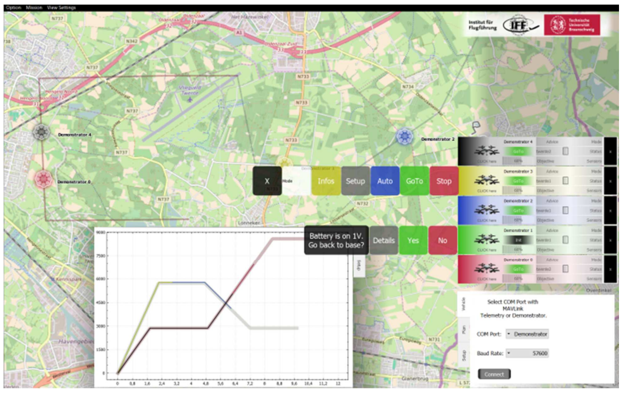

Figure 2: Existing RPAS ground station interface at TUBS

For low-level ATC there needs to be a possibility to monitor the traffic and especially supervise any conventional air traffic interactions with RPAS in the relevant area. Therefore, the data from RPAS and conventional air traffic needs to be collected and displayed at a ground based-control station. In Figure **2**, the mentioned prior work for this control station is depicted. Adaption to the needs of MoNIfly will enable the project to investigate special needs and limitations of RPAS surveillance as well as study encounters between conventional traffic and RPAS traffic thoroughly. It can also be of use in public presentation of the project, as it can display (and possibly replay) traffic situations and the results of MoNIfly.

Although past research with respect to integration of drones into general aviation air traffic and options for de-confliction exists [2], it has been shown that for operations in visual conditions which rely on see-and-avoid principles, drones have to be equipped with specific sensors, effectively transforming them into sense-and-avoid vehicles. Since these sensors are very costly in comparison to low altitude drones in the open category, i.e. consumer electronics, general availability of these sensors is unlikely. As an alternative, the MoNIfly approach is an ambitious change to the principle of sense-and-avoid, effectively transferring the sense part to the mobile network system and the avoid part to a joint low altitude traffic control system.

Further, the approach of using cellular signal infrastructure, which by design is generally suitable to low level operations as it initially targets ground services, for this type of drone services is new. Concepts so far have relied on satellite based or inertial positioning services without exchange of position information. Communication has been achieved using different types of wireless datalink, also including cellular networks. This concept advances on these initial strategies through integration of known solutions into the air traffic environment and transfer to the cell tower infrastructure.

Cellular network providers are gaining interest in the aviation market, with large providers starting to create networks specifically for business aviation use [3]. On a technology level this approach can be considered comparable, although the regular cellular network is particularly suitable to low altitude operations. Cellular networks used for aviation purposes today are intended for data exchange at altitude. The scope of this project requires the cellular network to be accessible for low flying vehicles, which includes considerations as to how reception in shaded areas, e.g. valleys, can be guaranteed. It is expected that the results of MoNIfly will lead to recommendations or requirements to cell tower operators to ensure feasibility of the validated concept.

As such, the proposed integration of drones into the present air traffic system can be considered a novel approach which at the same time constitutes a requirement to successful implementation of future unmanned operations in low altitude airspace. It also serves as suitability study of which some results will likely be transferable to unmanned operations in other types of airspace and operational environments (e.g. higher altitude, airport terminal area). Also application to drones in the certified category, e.g. for take-off and landing, is thinkable. The concept can be considered innovative due to the combination of the known and proven technology of cellular networks with the problem of future air traffic demands.

4. THE MONIFLY TEAM

Stakeholder knowledge is of increased importance to this project, which is why each of the involved partners provides expertise in a specific field of the addressed scope. The project team currently consists of four partners; a fifth partner is in the process of joining the consortium. For the realization of the MoNIfly concept, the partners each offer different areas of expertise for the different aspects of the project, bringing together knowledge in ATM research with drone operators, drone manufacturers and communications experts.

The project is led by Technische Universität Braunschweig (TUBS, Germany) who possess an extensive background in air traffic management research and the analysis of current operational procedures. Additionally, TUBS operates a variety of manned and remotely piloted research aircraft which have been used for different projects in the fields of precision navigation, procedure development as well as air traffic de-confliction and swarm maneuvering. The combination of these areas of expertise allows TUBS to provide valuable insight into the state of the art of air traffic regulations with respect to manned and unmanned air vehicles as well as providing a manned research aircraft for concept validation.

The Royal Military Academy (RMA) of Belgium also provides high levels of expertise in the field of ATM research. RMA brings specialized insight into the current and future state of air traffic and ATM to the table. It will provide relevant information on current methods for conflict detection and avoidance and will further assess any potential barriers for future implementation of the concept.

UAV International (UNL, The Netherlands) as drone operator has gained experience in a variety of drone operating domains, including cell tower inspection, as well as in the design of high-performance drone components. Aerialtronic (ATR, also from the Netherlands) as drone manufacturer will enable MoNIfly to tailor drones to its needs, enabling integration of the LTE modem and establishing communications between the flight computer and the modem. UNL is also involved in the development of regulatory guidance material which contributes to the applicability of the concept.

This joint experience will allow for realistic field tests to be carried out based on operational scenarios to validate the developed infrastructure. UNL will also provide access and support at the uncontrolled Airport Twente-Enschede which will be used as test environment for the demonstration of the MoNIfly approach.

A fifth partner will join the consortium in October 2017, developing and providing the mobile network infrastructure. The reason for this is that the initial partner for the project changed business priorities and left just prior to the start of the project. At the time of writing, the contracts have not been signed yet, which is why the new partner is not disclosed in this paper.

The project started in June 2017 and will last for 3 full years. The field validation and demonstration campaign is scheduled for the last year of the project.

5. ACKNOWLEDGMENTS

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6. REFERENCES

[1] EASA, „Introduction of a regulatory framework for the operation of unmanned aircraft“, 2015.

[2] C. L. Tallec, "VFR general aviation aircraft and UAV flights deconfliction," *Aerospace Science and Technology,* pp. 495-503, 2005.

[3] Flyingmag, "Two Major Aviation Cellphone Networks Launching," October 2014. [Online]. Available: http://www.flyingmag.com/avionics-gear/pilot-supplies/two-major-aviation-cellphone-networks-launching. [Accessed June 2015].

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