Droneway: A Viable Initial Scenario for UTM using Private Wireless Network for Localized BVLOS

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***Abstract*—Autonomous vehicles, such as UAS (Unmanned Aircraft Systems), are considered a key player in the future of fast and efficient delivery of purchased products from virtual stores. This paper addresses UTM (UAS Traffic Management) with a suggested system, leveraging existing transmission line as pathways for UAS beyond visual line of sight (BVLOS), between the autonomous flying device and a controlling central office. These pathways are called here as "Droneways". It is expected that this UTM solution for localized BVLOS could be an initial stage of an inexorable future of flying autonomous drones, given that the utilized area suggested here is geographically limited by existing transmission line pathways, therefore not addressing the traffic management of UAS ubiquitous need. Nevertheless, the early adoption of flying drones as autonomous delivery devices fills a gap on today's remote area parcel delivery needs, brings economic benefits, and serve as a learning scenario for the future of flying drones traffic management.**

***Index Terms*— Air traffic control, Control systems, Traffic Control, Unmanned aerial vehicles, Vehicular and wireless technologies.**

I. Introduction

THE growth of e-commerce is evident, and one critical area for further development is the fast and efficient delivery of purchased products from virtual stores. Autonomous vehicles, such as UAS (Unmanned Aircraft Systems), are considered as a key player in the future of such deliveries [1]. A current and prominent issue for a mass adoption of autonomous UAS, as an efficient and fast delivery of products, is the traffic management of such devices [2][3][4][5]. Integrating UAS into the airspace system is not an easy task. By its own nature of being an aircraft system, UAS can fly in many areas with sometimes undesired consequences. It has been seen cases of UAS flights near major airports, causing a total shut down of airplanes landing and taking off, with significant economic impact. For instance, during December 2018, right before a major holiday, about 1,000 flights were cancelled, or at least impacted, at Gatwick Airport near London, England, following reports of drone flying close to the airport, affecting approximately 140,000 passengers and resulting on a severe economic impact [6]. Therefore, it is unquestionable the need for some kind of air traffic control for UAS.

In the United States, the Federal Aviation Administration (FAA) regulates permissible areas of UAS usage following primarily the Title 14 CFR (Code of Federal Regulations) Part 107: Operation and Certification of sUAS (commercial / civil) [7]. The key boundaries to allow a UAS flight are, among others:

1) UAS weights less than 55 lbs. (< 25 kg).
2) Flight allowed below 400 ft. (< 122 meters) above ground level (AGL).
3) Maximum speed of 100 mph (< 161 km/h).
4) Visual Line Of Sight (VLOS) between UAS and Certified Remote Pilot In Command (RPIC).
5) Daylight flights.
6) No operation over people.
7) No operation on controlled airspace, Class A to E, unless previously authorized.

The authorization for operation on controlled airspace is currently obtained by two processes: Low Altitude Authorization Notification Capability (LAANC), and by DroneZone [8]. LAANC has been deployed in the entire continental United States, and could be obtained near-real time via mobile or desktop / laptop application using predefined authorization companies called UAS Service Suppliers. DroneZone is used when it is required an airspace authorization and a waiver from part 107 rules (i.e., exception to the key boundaries before mentioned) [9]. DroneZone requires a pre-registration of the UAS and more time to obtain approval, within 90 days.

As seen above, it is not an easy task to allow UAS to fly ubiquitously, keeping control to the set of rules in part 107 and providing the required authorization for exceptions. One particular regulation, the required LOS from the Remote Pilot In Command (RPIC) to the flying UAS, limits considerably the autonomous component of the UAS. Recent studies are seeking Beyond Visual Line Of Sight (BVLOS) conditions that would promote safety while extending the effective use of UAS [10][11]. Next chapter suggests a system to address the BVLOS issue by limiting geographically the path of UAS, called here as Droneway.

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II. The Envisioned System

The envisioned system consists in utilizing transmission line pathways as localized regions for BVLOS UAS flying zones. Such pathways, or Droneways, are regions with no people transit, so the criteria of 14 CFR 107, regarding no operation over people, is naturally met. Another critical point is that transmission line pathways have been deployed considering nearby airports, so there is a high probability of no intersection with controlled air space (Classes A to E). The suggested Droneway system considers the availability of existing towers, designed as transmission line support, for collocated towers to a dedicated Private Wireless Network (PWN) providing specific coverage for the localized BVLOS region. Here, the PWN provides the Command and Control (C2) link, including for real time location of each flying device [12], instead of using more expensive passive radar systems for tracking UAS. The private wireless network provides not only continuous communication between the many UAS to a central office, but also video surveillance from strategic points for ad hoc inspections. Figure 1 shows an existing transmission line pathway that could be used as a Droneway.

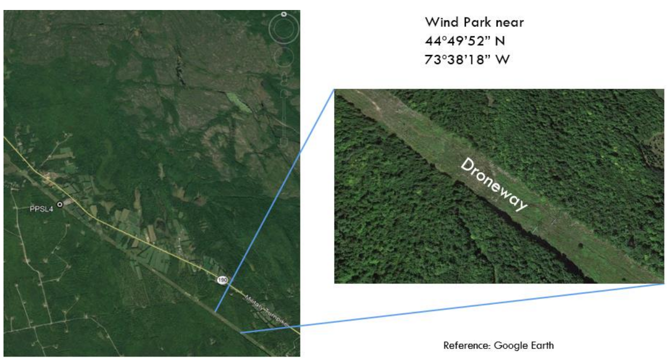

Fig. 1. Transmission Line pathway used as Localized BVLOS area for UAS utilization – Droneway. Wind Park near 44º49'52"N, 73º38'18". Reference Google Earth.

The elements of the Localized BVLOS Droneway system is as follows:

- UAS equipped with Detect and avoid technology, GPS and radio communication from PWN requirements (frequency, etc.).
- Private Wireless Network (PWN) providing coverage primarily to the Droneway, with high gain, narrow beam width directional antennas. Intrinsic handoff mechanism from PWN providing continuous communication to UAS.
- Collocated from transmission lines (reuse) or stand-alone towers. Typical height of transmission lines tower varies from 50 to 180 feet (~15 to 55 meters) [13]. Using for PWN the existing transmission lines towers reduce the overall system cost.
- Backbone for interconnecting PWN base stations to a central office, that could be achieved by OPGW (Optical Ground Wire). An optical fiber inserted inside the ground wire of transmission lines could provide band width as needed. Including for traffic control video surveillance cameras.
- Central Office with Operation and Supervision Systems (OSS), collecting data for all UAS in the Droneway, their precise location from GPS readings, and AAA function (Authentication, Authorization and Accounting).

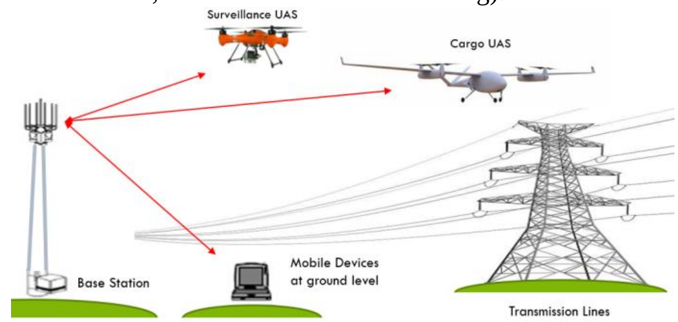

Fig. 2. Representation of the envisioned system for Localized BVLOS, including Base Station, Surveillance UAS, Cargo UAS, Mobile Devices at ground level and Transmission Lines.

As seen before, the 14 CFR part 107 authorized maximum altitude above ground level (AGL) for UAS flights is 400 feet (~122 meters). Since the typical tower heights for transmission line is less than 180 feet (~55 meters), there is a considerate available space for UAS utilization. Traffic rules can therefore be stablished by defining a two-way Droneway where the right "lane" would be used to go, and the left "lane" would be used to return. Assuming a typical value of horizontal 170 feet (~52 meters) for the Droneway [14], each way could be considered 85 feet (~26 meters), giving enough space for lateral displacement due to wind gust, for instance. As for the vertical component "lane", from the three-dimensional characteristic of the Droneway, an emergency lane, for surveillance or patrolling, could be considered at an altitude AGL between 328 to 394 feet (~100 to 120 meters), a cruise lane, possibly for platooning, with altitudes AGL between 262 to 328 feet (~80 to 100 meters), and a slower speed lane, for transition or preparation to landing, with altitudes AGL between 196 to 262 feet (~60 to 80 meters).

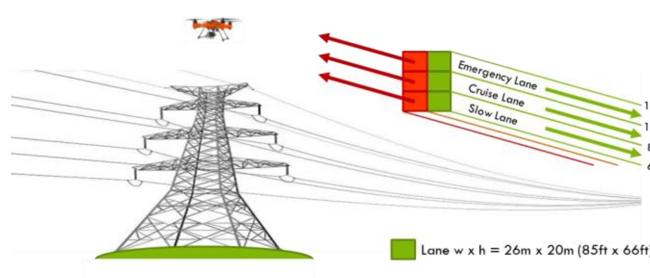

Fig. 3. The concept of vertical "lanes" for better traffic management. Emergency lane, cruise lane and slow lane. Each lane w x h = 26m x 20m (85ft x 66ft).

For speeds, the maximum speed allowed from the 14 CFR part 107 is 100 mph (~161 km/h). It seems a very good top speed, since one immediate concern while flying over transmission lines is that a sharp turn of 90º, a right angle, could be present in the Droneway. The compromise between speed and the ability to perform sharp turns will be dependent on the UAS device. The mitigation for this hardship is that the flight plan for each UAS specifies the pre-programed speed for every part of the course. Such planning measure of pre-defined speeds guarantees the ability to perform sharp turns. Additional studies, considering the UAS characteristics, should be carried out in this area.

Air traffic control for both manned and unmanned aircraft has been a critical component for the future of aviation. For instance, Automatic Dependent Surveillance Broadcast (ADS-B) system has been derived considering the empowerment for the aircraft to broadcast its location and intentions [15]. The trend of distributing control to the end devices, as an approach to expedite decision making and increase safety, is seem in many areas of telecommunication. In fact, hand-off's (and soft hand-off's) mechanisms between base stations in cellular communications, to guarantee continuous communication with a mobile device, has been a proven and efficient approach of this delegation trend for the past years. Currently, one could use this intrinsic characteristic of a Wireless Network to guarantee continuous connection between the UAS and the Central Office. As for non-registered UAS or extraneous flying devices or animals (e.g., birds), the same UAS, equipped with detect and avoid technology, could report to a central command any presence of unidentified objects in real time. Additionally, video surveillance cameras, as used in train tracks and highways, could be added as extra support for safety and efficient operation. Autonomous systems are constantly evolving and are a clear trend in the transportation industry.

III. REAL CASE FOR A PILOT SYSTEM

New York State has strict rules for gas emission [16] and known for heavy traffic in its roads and highways. So, options for low gas emissions transportation to replace diesel-based trucks are welcome for this state. With that in mind, a transmission line path was selected in the state connecting Niagara and Saint Lawrence to Clark Executive Center (EC), as the Central Office for Command and Control.

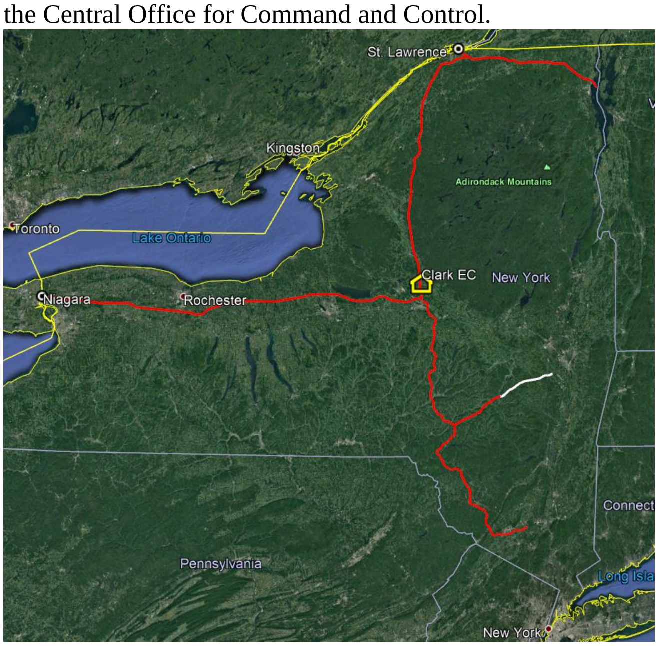

Fig. 4: Transmission Line pathways selected as Droneway in the state of New York. (Google Earth).

In Figure 4, the transmission line path considered for the real case pilot system is seen as a red line, totaling a linear 730 miles (~1,175 km). From Clark Central Office going south, the Droneway considers a bifurcation with one path going towards Albany, and another going towards New York City. Further studies could consider a Droneway going up to the periphery of dense urban centers such as NYC. This pilot is focused on addressing rural areas, with long stretch of unpopulated areas, with hilly terrain, where using autonomous UAS is highly beneficial. With the Droneway defined, the goal is to provide a linear coverage with a Private Wireless Network to the traffic control of UAS. For that, a propagation simulation tool called EAGLE2 is used as radio frequency (RF) coverage area prediction [17][18]. The input parameters are as follows:

1. Terrain Data DTED2 with 1 arc second resolution (~30 meters) [19]
2. xSpec Wireless Private Network (formerly known as iBurst) at 1790 MHz with 5 MHz band width. - ERP: Transmitter = 43 dBm (max); Receiver = 27 dBm.
3. Directional 18 dBi Antenna with 13º horizontal beam width, and 37º vertical beam width.
4. Tower heights from 100 to 200 feet (~30 to 60 meters) AGL.
5. Receiver height 1.5 m AGL, as worst-case scenario, to mobile devices. Higher altitudes result in better coverage, up to the 400 feet AGL limit.

With the above specification, propagation simulations were carried out and tower sites were selected in optimized points to promote the maximum coverage with the minimum amount of base stations. As seen in Figure 5 below, a part of the path between Saint Lawrence and Clark EC is reproduced to show the hilly terrain conditions encountered at the Adirondack Mountains, with vertical to horizontal proportion of 1:52. So finding the compromise between coverage and number of base stations required few interactions.

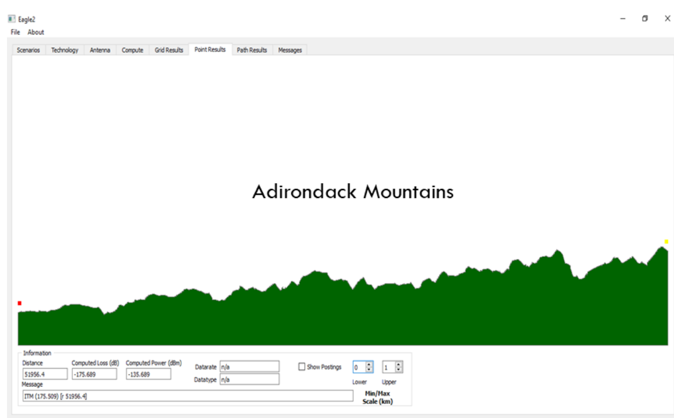

Fig. 5: Straight line between base station locations on the Adirondack Mountains (vertical to horizontal distances 1:52)

Gifford Hills is another region where finding the proper linear coverage was challenging. The area is sparsely populated and very hilly. The objective was to keep the RF energy within the Droneway, with the least amount of leakage to the surrounding areas. Figure 6 presents a 3-dimension view of the EAGLE2 propagation tool, with the resulting coverage for the Droneway near Norwich and Oneonta cities.

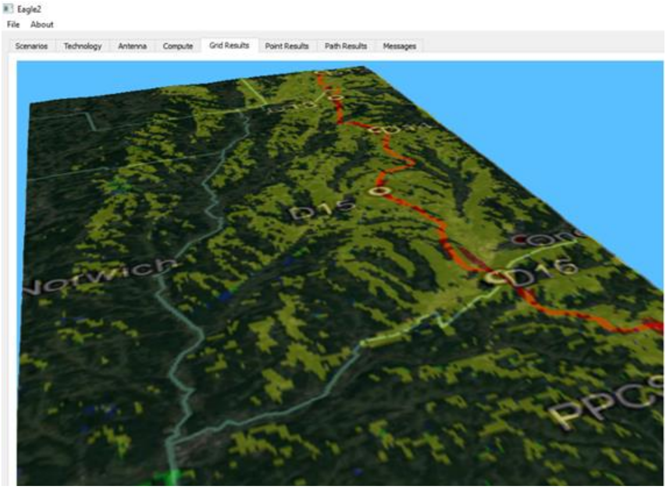

Fig. 6: Yellow coverage over red Droneway on Gifford Hills

After few interactions, the resulting number of base stations, needed to provide coverage to the linear 730 miles Droneway was 46. Out of these 46, 44 were two sectors base station with the 13º horizontal beam width, and 2 were defined as omni antennas, with 10 dBi gain. These 2 were needed when a junction (or bifurcation) on the Droneway was present, case at the Clark Executive Center. Clark EC was selected to host the Central Office for C2 (Command and Control) of the UAS fleet using the Droneway.

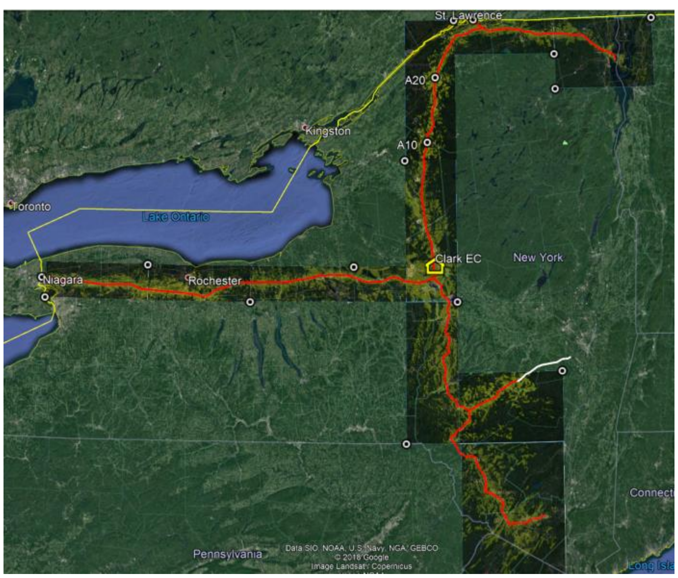

Fig. 7: End result of 46 Base Stations covering the Droneway in New York.

IV. Conclusion

This paper presents a viable scenario for Localized Beyond Visual Line of Sight (BVLOS) system for Unmanned Aircraft System (UAS) traffic management, by limiting the UAS utilization to a Droneway, as an initial step for ubiquitous UTM (UAS Traffic Management). This entry level step could help the industry start a safe, efficient and economical way of cargo transportation, reducing gas emissions and offloading roads and highways, immediately. Future steps would be a pilot deployment and the adaptation of the Executive Control system from a typical Private Wireless Network (PWN) central office to a customized UAS traffic control, including new Operation and Supervision Systems (OSS), such as Authentication, Authorization and Accounting (AAA) for all UAS utilizing the Droneway.

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From 1987 to 1988 he worked for the Brazilian Army (CTEx) in microwave devices measurements and rain attenuation of electromagnetic waves in the microwave band, where he developed the research for his master's thesis. During the summer of 1991, he was with Telesis Technologies Laboratory (Pac Tel) working in the FCC Experimental License Project for Personal Communication Services (PCS).

Dr. Maciel has received the 1993 Neil Shepherd IEEE Best Propagation paper award, has more than 25 years' experience in the telecommunication industry, from AT&T Bell Laboratories to Alcatel-Lucent and Nokia. Now is with Agya Corporation, engaged on IoT, UAS/UTM and Cybersecurity projects.