# Position: DroneVLC: Visible Light Communication for Aerial Vehicular Networking

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## ABSTRACT

Drones have opened up a vista of opportunities for novel applications, ranging from 3D mapping to agriculture to door delivery of products. This paper positions the idea of enabling visible light communication (VLC) technology on drones. VLC on drones provides a new communication modality between drones and their specific application targets in air or ground, enabling novel applications in the VLC ecosystem. For example, drones could provide a fast and reliable VLC based Internet hotspot, reliable communication links for air–traffic control and even enable inter–aerial–vehicular communication. This paper discusses different use–cases for VLC on drones and the key research challenges in realizing the technology.

## 1 INTRODUCTION

The advent of unmanned aerial vehicles (UAV), or *drones*, in the commercial arena has enabled new kind of mobile applications. Thanks to the advances in 3D printing, robotics, and miniaturization technology it has become possible to realize off-the–shelf drones that can hover across significant heights and ranges. Apart from the suite of sensors that get embedded in drones today, they are also equipped with radio wireless technologies which particularly serve as control channels between the drone and the controller device/machine on the ground. Today, drones are being treated more as a smartly navigating robotic vehicle with different types of sensors attached, and not necessarily as a communication device. Therefore, it bears to ask the question as to *what if drones were equipped with a full wireless networking stack and treated as a typical networking device?*

Drones as a communication device is not only interesting but also could become a necessity keeping in mind the rapid advances in unmanned and manned aerial vehicular technologies, as well as the rising challenges for today's radio wireless technologies. We are already at the cusp of a revolution in vehicular technology where the idea of flying cars [1] and commercial space travel [2] is not science fiction anymore. The idea of enabling communication through drones and treating it like any other Internet–of–Things (IoT) device can be treated on par with such technological breakthroughs.

roviding a high–speed Internet connection on the fly to such aerial–IoT vehicles will become even more challenging than today's situation as radio wireless spectrum is becoming heavily congested to the high density of devices and their high throughput requirements.

In this paper, we position the idea of using VLC for aerial vehicular networking. We propose the DroneVLC concept through which aerial vehicles equipped with VLC units will communicate with other aerial or ground VLC equipped targets. The targets include devices such as smartphones and/or machines such as cars or even infrastructures.

VLC is an attractive proposition for drone communication because: First of all, communicating with/to a drone from the ground requires the transmitter/receiver unit to point vertically towards the sky. Unlike a terrestrial VLC link, ground–to–air links and aerial–only links are free of any obstacles and thus provide a clear line–of–sight (LOS) path; having a clear LOS path even when mobile can ensure stable high signal–to–noise–ratio (SNR) and thus reliably high throughputs. Secondly, VLC due its highly directional communication can enable multicast links from a single drone, which otherwise can be extremely challenging if using radio wireless due to signal interference.

DroneVLC opens up plethora of opportunities for novel applications that can benefit from ground–air and air–air communication. However, to realize these applications it is important to make significant advancements in VLC technology. State–of–the–art VLC systems are largely limitted to short ranges. While lasers have long been used for long–range free–space optical wireless links, the design complexity and cost incurred are high. Long–range VLC systems can be orders of magnitude cheaper and adaptable than today's laser free–space optics. In addition, today's VLC data–rates are orders of magnitude lower than what their theoretical capacity models estimate [3], mobility is largely limitted limitted to extremely controlled settings. Achieving long–range, high throughput and mobility at the same time remains an open research challenge to the VLC community.

This paper discusses VLC in light of the key research challenges entailed to realize a novel use–case of using drones as communication device. We bear to see DroneVLC as a system where VLC can be applied. In the rest of this paper, we discuss a few key use–cases of DroneVLC and the corresponding advancements required in the VLC area to realize the same.

## 2 DRONEVLC USE–CASES

The use–cases for DroneVLC can be categorized within two modes of operation: (i) Aerial and Ground, and (ii) Aerial–Only. Applications can operate in either or both of these modes depending on their requirements and transmitter and receiver placements. The transmitter and receiver placements depend on the application requirements which will essentially dictate whether the communication has to be unidirectional or bidirectional.


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## 2.1 Aerial and Ground

In this mode of operation drones communicate with VLC targets on the ground. This can enable plethora of novel applications as well as improve communication quality of existing applications.

For example, DroneVLC can provide *on–demand* Internet hotspots on specific geographical locations. In addition, such drones could also be designed as network relay nodes for directing data traffic from ground devices. In particular, inter–vehicular communication using radio can become extremely congested in heavy traffic scenarios and using such DroneVLC relay links can help improve vehicular networking throughput. DroneVLC can be used for multiple–access communication between manned aerial and ground units. For example, traffic management from air–traffic control towers can be made more efficient by having the control station communicate with multiple airplanes at the same time using VLC technology.

## 2.2 Aerial–Only

In this mode DroneVLC units (manned or unmanned) communicate with one another. While in most of the cases these units will constitute manned and robotic aerial vehicles, it can also include stations deployed in sky – for example, air balloons. Through aerial–only links DroneVLC can enable inter–vehicular communication between flying cars and other future aerial robotic platforms. Line–of–sight (LOS) communication between aerial vehicles can enable secure network links between airplanes, which can further improve air–traffic safety and management in airports. Aerial robotic swarms can be enabled with VLC links for achieving low–latency and secure communication between the robots in the swarm, thus improving reliability in robotic swarm rescue missions.

# 3 RESEARCH CHALLENGES

Today, VLC is going through a transition from conceptualization to standardization and commercialization. The fact that NASA is already welcoming the idea of VLC in space research [4] and the recent design ideas on VLC for satellite communication [5] provide a timely relevance for DroneVLC technology. However, enabling the diverse set of applications using DroneVLC requires fundamental advancements in VLC technology. We discuss the key design considerations and their associated research challenges below:

(1) Ground–Air communication is asymmetric: Ground units will be exposed directly to the ambient light as they have to be directed towards the sky to communicate with the drone. Such a placement increases the reception of ambient light and thus increased noise at the receiver. Aerial VLC units can be placed at vantage positions on the drone (area with a shade) as they only need to be pointed towards the ground, and the ambient light's effect would hence be indirect. Achieving high signal–to–noise–ratio (SNR) reception at the VLC receiver will be a key research challenge to operate in these modes.

(2) High data rate is key: Aerial VLC hotspots will be useful only when VLC can provide significantly high data–rates. In this regard, state–of–the–art VLC architectures have a milestone to cross in achieving high data–rates.

(3) Long range will be a fundamental requirement: Communicating across aerial units will require long range access. The fact that LOS paths are more accessible in aerial links supports the feasibility of long range VLC, however, research in VLC technology is yet to take large strides in that direction.

(4) Fast–speed mobility will be a new dimension: VLC is highly directional and drones are highly mobile. These conflicting properties make it very challenging to locate VLC units using a drone. Moreover, aerial vehicles are essentially built to move fast. This brings a new dimension to address in terms of mobile architectures for VLC. Tracking fast moving objects in air will be an imminent requirement and has to be tied in with high–data rate VLC architectures.

(5) Energy : Even with advancements in low–energy light emitting diodes, photodiodes and image sensors, the energy budget for VLC is much higher than radio communication. Energy management will play a key role in DroneVLC architectures.

Through this paper, we position key fundamental challenges in VLC with relevance to a novel use–case for VLC. We hope that these discussions bring a perspective to the community in understanding the challenges of VLC technology and generate discussions to advance new use–cases such as DroneVLC .

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