Wireless Networking for Autonomous Mobile Smart Cameras

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***Abstract*— Networked flying devices such as smart cameras equipped with sensors are increasingly being deployed to capture real-time video and images, especially from locations not easily accessible. However, the management and control of the networked flying smart cameras, comes with significant challenges in what concerns the retrieval of high quality video, and the control of a set of autonomous devices. Such challenges are related to the transfer of large amount of video with low delay, as well as low latency and high resilience needed for the coordination of the flying mission of each device, aiming to cover a large area in the shortest possible time. In this context, this research aims to investigate novel wireless networking protocols aiming to assist develop flying smart camera networked systems able of capturing and transmitting high quality images and video over large geographic areas. The focus is on networking approaches that encompass inter-vehicle communication, cellular wireless networking and fog/edge computing.**

Keywords*— *Wireless networking, Autonomous flying devices, cellular communications, edge computing.

I. INTRODUCTION

Research interest in smart cameras arose both in academia and in industry in recent times, namely to extract application-specific information from captured video and images. In this context, single camera systems focus on the on-board integration of different sensing embedded vision tasks. For large area coverage, it is expected that a distributed system of smart cameras will be able to collaborate by coordinating flying information and by exchanging captured video in order to achieve a fast coverage over large geographic areas [1]. Deploying distributed camera systems poses several challenges but, the applicability is large such as: forestry inventory; urban city classification; monitoring of mine fields.

A distributed set of flying smart cameras may be operated based on a cloud system [2], which may monitor all requests. However such system may lead to a high communication overhead, high latency, and low resilience [1]. Facing such constraints, it is desirable to develop autonomous distributed camera systems able of enhancing local coordination in decision making [3], increase network flexibility, scalability, collaboration and robustness to allow for quick self-organization in reacting to emerging situations [4].

Therefore, the main goal of this research is to investigate autonomous smart camera systems seeking solutions to challenges in smart camera collaboration and wireless communication to support the operation of autonomous smart cameras over large geographic areas. Especial attention will be given to the combination of inter-device communication (e.g. cooperative relaying), cellular networking and edge computing, in order to reduce the latency of communication and increase system resilience, while taking into account energy constraints.

For this propose, computational efforts (e.g. flying control and video analysis) need to be processed locally in order to conserve energy consumption; Latency reduction can also be achieved by anticipation, which requires the coordination of the different networked devices in the assessment of current conditions.

II. STATE OF THE ART

This section explores relevant state of the art for the development of autonomous flying camera systems, namely wireless communications and distributed computing paradigms.

A. Wireless Communications

In what concerns wireless communications, 5G technology is expected to provide support for Air-to-ground high data rate transmissions [5]. On the other hand, to facilitate reliable inter-mobile device communication, it is a requirement in support for Air-to-Air communications to enable design of temporary network infrastructure for transfer of data in real time. Opportunistic wireless communications [6] and Cooperative wireless relay networks [7] propose frameworks enabling data transmissions from remote areas opportunistically.

However, deployment of Air-to-Ground communications differ from Air-to-Air channels because Air-to-Ground signal propagation channels are susceptible to blockages which contributes to coverage challenges and limited data bandwidth transfers [8]. In providing solutions to these challenges, models have been devised to facilitate minimal Air-to-Ground path loss and or optimize aerial platforms with onboard radio heads to provide maximum coverages [9]. Other solutions include design of interference-aware path planning schemes [10], to assist reduce interference in Air-to-Ground UAV signal propagation.

B. Distributed computing

Distributed computing encompass Cloud, Fog and Edge paradigms. Cloud provides collaboration, coordination and computational distribution among devices but may be subjected to high latency, which is not suitable for time sensitive applications. Edge or Fog computing are constrained in battery lifetime and CPU requirement for tasks intensive demands, but offer computational task distribution, mobility support and are in close proximity to end devices providing real time services. Analysis of edge and fog computing [11] show that they provide intermediate computing resources to facilitate tasks realization in place of cloud. Their proximity to end devices demonstrates outstanding capabilities in providing real time services compared with cloud in delay jitter, latency and data bandwidth transmissions. In order to influence effective use of edge and fog computing technologies in autonomous distributed flying camera drones, computational resource offloading algorithm have been proposed to facilitate fault tolerance and robustness [12], as well as leading to sustained device lifetime [13].

III. PROPOSAL TO ADVANCE THE STATE OF THE ART

The analysis of the state of the art showed the need for extended research in advancing support for the efficient operation of networked autonomous flying camera system, based on the combination of 5G/LTE and inter-device communications (e.g. cooperative relaying), as well as the standardization of systems architecture for edge/fog computing paradigm to facilitate optimum system performance. It is also clear from the analysis that the challenges in computation task distribution, path formation planning, mission coordination, and self-organization needs further investigation to facilitate the successful deployment of networked flying systems.

Therefore, this research aims to contribute to advance the state of the art by investigating new advanced wireless networking solutions encompassing air-to-air communication, 5G/LTE networking and edge/fog computing, namely:

- ❖ Providing a detailed representation of a model for aerial networked system of autonomous smart cameras.
- ❖ Investigating an efficient combination of cellular communications and 3D cooperative relaying to support self-organization properties of autonomous systems (e.g. low latency, high resilience) and transmission of real-time video (e.g. low latency, high throughput).
- ❖ Investigating proper usage of edge/fog computing to support the delivery of real-time video, namely in what concerns the coordination between edge devices to support video quality adaptation (e.g. different edge devices may be selected as gateways of a multi-hop wireless video transmission based on latency requirements and wireless network conditions).

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