Context-Aware Navigation Protocol for Safe Flying of Unmanned Aerial Vehicles

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***Abstract*—There is an uprising in research attention to Unmanned Aerial Vehicles (UAVs) to explore and exploit their properties that facilitate mission-oriented applications. Shortly, multiple UAVs will fly together to create a high-traffic UAV network and require robust control to avoid collisions. A collaboration of flying UAVs in handling route navigation and obstacle avoidance is a necessity to have safe urban air mobility. This paper proposes a Context-Aware Navigation Protocol using IP-based communication over 5G Vehicle-to-Everything (5G V2X), which is a currently popular mobile communication technology.**

***Index Terms*—Unmanned Aerial Vehicle, Safe Flying, Collision Avoidance, Path Planning.**

I. Introduction

The rapid popularity of Unmanned Aerial Vehicles (UAV) resulted in their several mission-oriented applications [1]. Those include patrolling, video recording, surveillance and inspection, parcel delivery, disaster management, and air taxis. This growth increases the need for the collaboration of UAVs in conflict detection and avoidance to ensure safe flights in the airspace. The recent technological progress explored Flying Ad-Hoc Networks (FANET) promoting flight cooperation [2]. UAV networks enable effective coordination in a multi-UAV environment. A coordinated flying network renders collision-free and seamless operations in a UAV network.

Sensing and detection in the UAV network environment relies on ranging sensors such as camera and LiDAR, and communications [3]. This work proposes cooperation among UAVs via lightweight sensing information sharing through 5G networks. Fig. 1 describes reliable UAV communication in shared airspace. We propose a Context-Aware Navigation Protocol using an IP-based drone network over a 5G-V2X for safe and secure flight. We employ a vehicular mobility information (VMI) option as proposed in [4], where the awareness message option is the cooperation context message (CCM) and the safety control message is the emergency context message (ECM).

The remainder of this paper is organized as follows. Section II summarizes related work. Section III describes our network design, and Section IV describes the implementation performance. Finally, in Section V, we conclude this paper along with future work.

II. Related Work

A couple of methods of avoiding collision in UAV network systems were proposed. Huang et al. [5] put up an application-specific UAV network deployment to avoid collisions. A novel mobility model relying on network clustering provides seamless connectivity in UAV networks and improves UAV coverage range [6]. The network enables cooperation among UAVs for efficient missions such as parcel delivery carry-out [7]. All the above methods did not exploit the benefits of a reliable 5G-enabled network to benefit three-dimensional (3D) mobile nodes. They also lack a consideration of handling obstacles appearing in front of an aerial vehicle. The mixed integer approach proposed in [8] proposes a 3D map to avoid collision risks. Though a multi-layered approach is exploited, only in fixed bidirectional path segments UAVs can cross from one layer to another. Our proposed strategy provides a more scalable and flexible approach enabling drones to cross from one layer to another with minimal impact on the safety of UAVs flying in that layer.

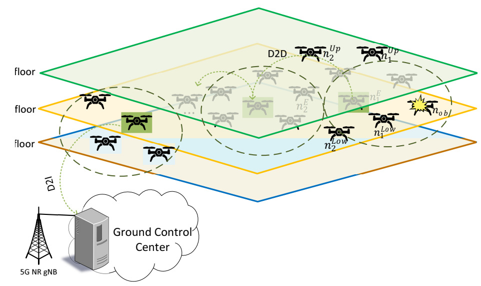
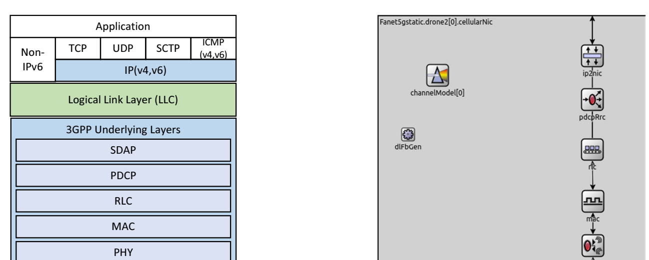


Fig. 1. An Emergency Communication and Handling for Heavy Traffic UAV Network.



(a) 5G V2X Protocol Stack (b) Simulation Structure

Fig. 2. 3GPP IP-based 5G V2X Communication Protocol Stack.

III. Design

Fig. 1 depicts a cooperative perception in the UAV network proposed by this paper. It is based on an ultra-reliable Cellular Vehicle-to-Everything (C-V2X) flying network. In

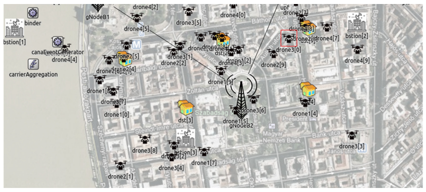


Fig. 3. A 5G-Enabled Network Simulation Scenario in OMNeT++.

this network, a Drone-to-Drone (D2D) with drones' direct communication (PC5) is established permitting drones direct interactions. The Ground Control Center (GCC) interacts in real-time with UAVs via network communication (Uu) to obtain traffic conditions for safe flights.

This model promotes Vehicle-to-Infrastructure (V2I) and Vehicle-to-Vehicle (V2V) communications enabling a UAV to communicate with both infrastructure and other UAVs over 5G V2X. Fig. 2 shows the UE's 5G V2X protocol stack (data plane). The 3GPP Underlying Layers consist of the Physical Layer (PHY), Media Access Control Layer (MAC), Radio Link Control (RLC), Packet Data Convergence Protocol (PDCP), and Service Data Adaptation Protocol (SDAP). The Logical Link Control (LLC) sublayer links the lower protocol layer (3GPP Underlying Layers) and the upper network layer (e.g., IPv6 layer, IPv4 layer), enabling V2X services for UAVs. Fig. 2(a) shows a general structure of the 3GPP 5G V2X protocol stack and Fig. 2(b) shows its OMNeT++ simulation structure.

The next section describes the simulation setup and results.

IV. Performance Evaluation

This section describes the simulation environment and the performance results of an IP-based 5G drone network.

A. Simulation Setup

We conducted a simulation of a drone network in OMNeT++ simulation framework [9]. We adopted a 5G simulation of the 5G New Radio User Plane Simulation Model (Simu5G) for INET & OMNeT++ [10] and adapted it for UAVs. Table I summarizes this simulation configuration.

B. Results

Fig. 3 demonstrates a typical UAV simulation in OMNeT++. The results in Fig. 4 show that the proposed network model keeps the risk of collision below 50% despite the presence of obstacles in the sky.

TABLE I
Simulation Configuration

Parameter	Description
FANET Network	length = 2 km, width = 2 km, and height = 200m .
Base Stations	4 base stations.
Destinations	5 mission destinations are deployed.
ECM Transmission Rate	Frequency of safety information transmission. The default is 10 packets per second.

V. Conclusion

This paper introduced a 5G-enabled network model suitable for UAVs. It introduces a message-sharing strategy to enhance the safety of the UAM vehicles through cooperation in emergency object detection and avoidance. As future work, we will extend our work and compare it with the existing baselines for its performance evaluation.

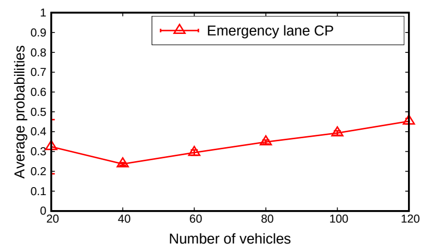


Fig. 4. Collision Probabilities.

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