Quadcopter Implementation of an in-network Centralized Collision Avoidance Algorithm in Programmable Data Planes

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Abstract

With next-generation 5G networks just around the corner, new opportunities and challenges appear. Applications in different trends (e.g., industry 4.0, agriculture, IoT, UAV) are gaining new envisions. Having high amounts of transmitted data and various network services, the network's capabilities need to grow together. Supporting Ultra-low latency (ULL) applications with extremely low loss and delay variation are required. Despite the major characteristics of the 5G networks, horizontal [1] [2] [3] (e.g., distance, nodes processing) and vertical (e.g., NIC, OS, Hypervisor, Application) delays affect the performance of end-to-end communication (Fig. 1).

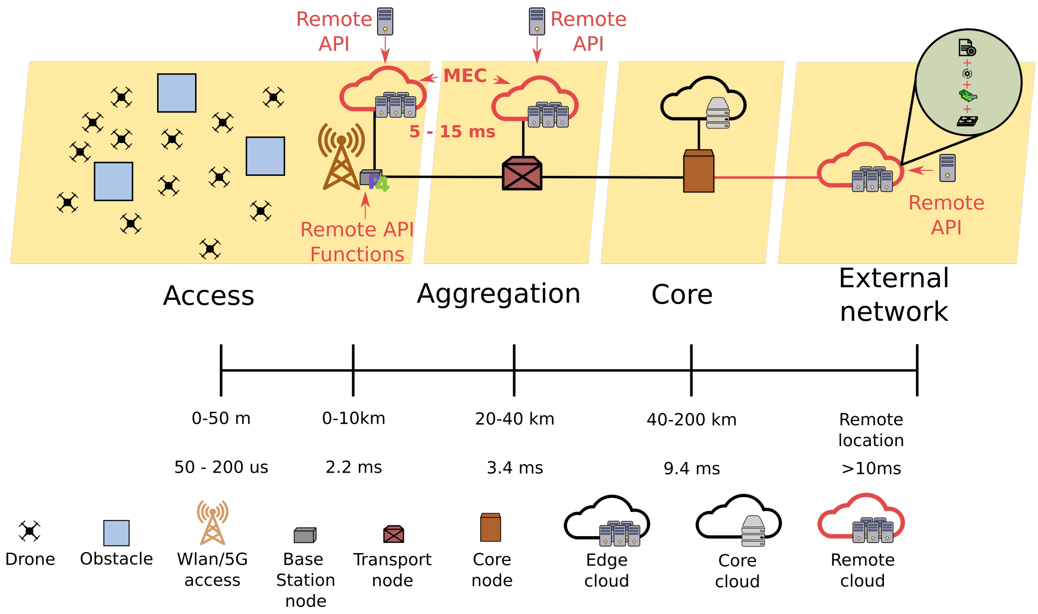

Figure 1: Quadcopter Scenario.

Unmanned aerial vehicles (UAVs), specially Quadcopters are becoming an important application powered by the new network characteristics. Having external sensors (e.g., camera, GPS, proximity sensor), UAVs can observe sudden changes in the operational area such as unexpected obstacles or even other UAVs. In such critical circumstances, not reacting in time (e.g., adjusting movements) can entail a severe impact, including collision, damages, or, more importantly, human injuries. To resolve this, each robot is directly connected to a powerful Remote API (Fig. 2) for continuous monitoring (e.g., complete view of the environment) and swift and precise interventions. [1]

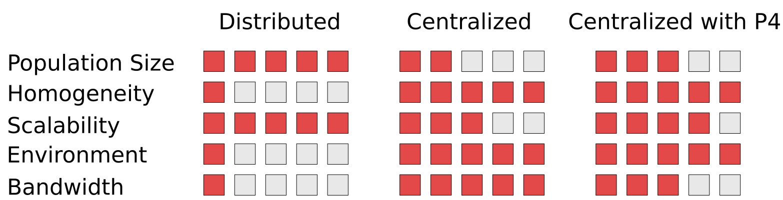

Figure 2: Comparison of Distributed and Centralized scenarios.

Nowadays, enterprises increasingly offload their business-critical workloads to the cloud to benefit from low infrastructure costs, high availability, and flexible resource management. However, have to face the unreliable (i.e., lossy and congested links, variation in delays) nature of today's network. In a Mobile Edge Computing (MEC) architecture, we bring cloud-computing capabilities to the network edge. However, we fancying

[1] Example of Remote API - UAVs integration with Mininet-Wifi using CoppeliaSim `https://github.com/intrig-unicamp/mininet-wifi/tree/master/examples/uav`, `https://youtu.be/k63Vbjhs-BA`

additional processing delays (e.g., switch, NIC, OS, Hypervisor, Application). If some control functions are offloaded to the network edge device (e.g., P4 switch), it is possible to reduce this processing time while directly responding from the network.

We propose an in-network Centralized Collision Avoidance Algorithm in Programmable Data Planes, bringing the benefits of a P4 device (e.g., High Performance, Reconfigurability, Protocol Independent). Adding the remote API functions in the edge device, we avoid the latency of the MEC (5 - 15 ms) or even of an external network (>10 ms) [4] [5] [6] [7]. Despite the possible limitations (e.g., complex operations, limited processing, limited memory), we argue the possibility of implementing an approach based on a Vector Field Histogram (VFH+) avoidance algorithm (Fig. 3). Having a complete view of the environment and adding the capability of avoiding collisions and even the extension to a path planning algorithm (Fig. 4).

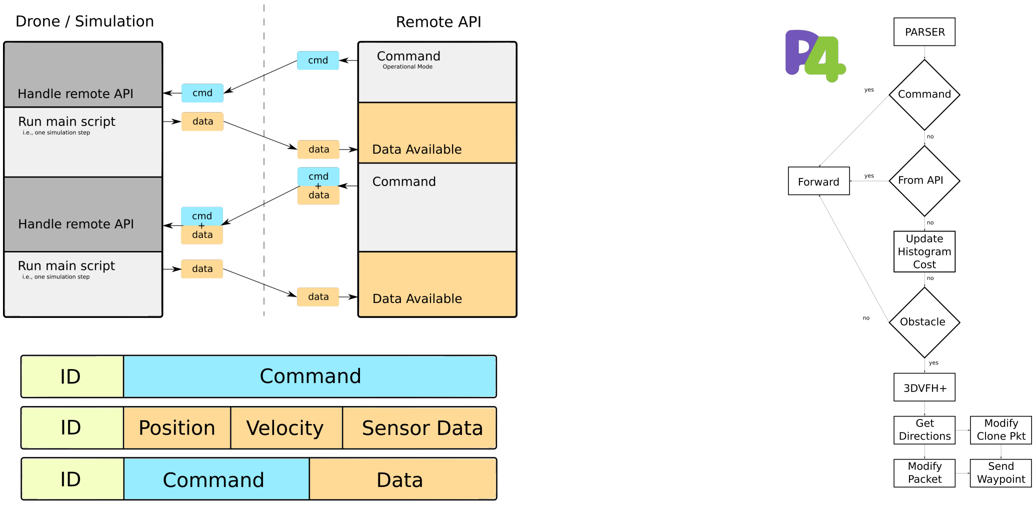

Figure 3: Drone/Remote API communication and P4 algorithm flow.

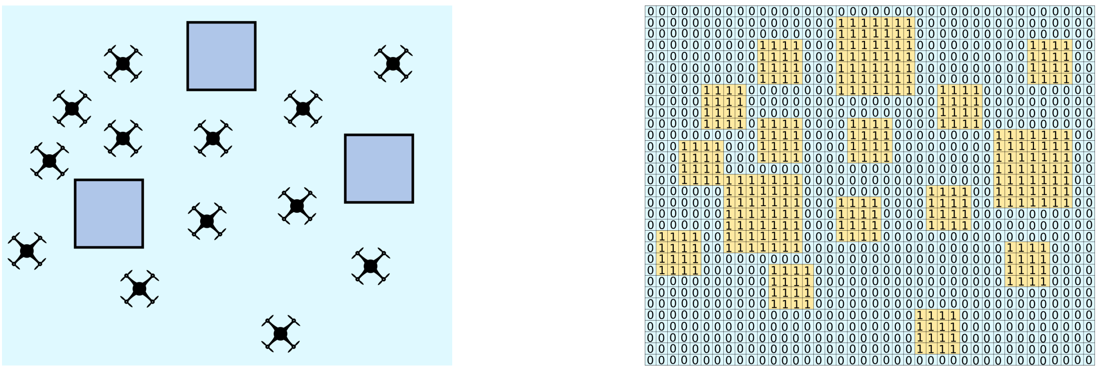

Figure 4: VFH+ avoidance algorithm.

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