This paper was presented at the conference:

Sánchez-Agüero, Víctor; Nogales, Borja; Valera, Francisco; Vidal, Iván. (2018) Flexible services deployment using Small Unmanned Aerial Vehicles for emergency situations. *XXXIII Simposium Nacional de la Unión Científica Internacional de Radio (URSI 2018), 5-7 de septiembre de 2018, Granada, España.*

Flexible services deployment using Small Unmanned Aerial Vehicles for emergency situations

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***Abstract*—The notorious advances in the Unmanned Aerial Vehicles (UAV) research area is allowing small UAVs (SUAV) to have an increasing presence in different civil applications. In the context of the 5GCity Spanish coordinated project, this paper considers the use of SUAV networks to support emergency services in critical and disaster situations. To solve the set of challenges presented in UAV networks, we present a general use case with the deployment of an NFV and SDN based solution and the different key enabling technologies. The whole deployment will be split into three stages during the project lifetime, with an initial integration using the 5TONIC European Open Research 5G laboratory and then with the different 5GCity project partners.**

I. Introduction

The emerging improvements in UAVS (Unmanned Aerial Vehicles Systems) technologies are enabling Small-UAVs (SUAV) to support a plethora of innovative services in the civil domain. They are coming on the scene not only replacing small planes like in precision agriculture [1] or surveillance [2], but also on new areas such as civil construction or civil infrastructure inspection [3] where aircrafts have not been used before.

However, from the network layer communication perspective, these small devices are showing a set of challenges that were not present in previous scenarios because of the special features of SUAV networks: e.g. it cannot be assumed that different SUAVs will always have a relatively static position or that it will always be possible for them to have a direct communication between each other. In fact, these small devices can change their position so fast that it is not clear that current algorithms specifically designed for mobile network scenarios (MANETs) are still valid. Some other challenges related with the limited resources of these platforms are also interesting so as to be considered in this article (battery consumption, processing limitations, etc.).

In this context, this article presents a use case that is being validated within the framework of the 5GCity[1] project. The main purpose of this project is to provide an adaptive management of 5G services to support critical events in cities. Several use cases are being deployed and in particular the one described in this article considers the design and implementation of a fast and flexible service deployment system in disaster areas, based on SUAV networks. Figure 1 presents a general overview of the use case and will be detailed later.

The organization of the rest of the paper is as follows: In Section II we overview the scenario motivation reviewing the main technologies that will be considered. Section III details the validation phases including the sub-cases that will be also deployed. Finally, section IV concludes the article and present some possible future alternatives.

II. Flexible Services Deployment in Critical Areas

One of the main goals of 5GCity is to support communications in critical events where a number of citizens is concentrated in a relatively small geographical area. One of the use cases under consideration is the design of a flexible service deployment procedure based on SUAV networks to support emergency situations like accidents or disasters where conventional communication networks may have been compromised.

SUAV networks (normally used in formations or swarms [4] [5]) and in combination with different actors, such as the Ground Control Station (GCS), or tactical (bigger) UAVs that may serve as relays, are quite useful in difficult locations where traditional services cannot be easily deployed, allowing for a fast, flexible and efficient service provisioning.

As seen in Figure 1, different public agencies like firefighters, police or medical departments may need to inter-operate to coordinate the activities. SUAVs have a critical role here since in addition to the Internet hotspot provisioning that can be enabled through them, they are capable of offering video surveillance, cellular network access, sensor information like temperature or air conditions, VoIP service, etc.

The communications operation is controlled from the Ground Control Station (GCS), that is normally located in a mobile shelter (truck) and is responsible for SUAVs position and traffic routing. These SUAVs may fly to the desired GPS position where they can eventually land to save battery and start their assigned mission (access point, AP, information relay, SIP server, etc.). SUAVs may also hover in a certain spot or follow a certain flight trajectory to carry out video surveillance, etc. The GCS is also responsible for node replacement, traffic routing among SUAVs (possibly using SDN) or even switching on/off radio interfaces depending on the load, to green the network. These operations take place over the control channel (LTE, or LoRA), which will be crucial to trade off the bandwidth and power consumption. The communication from the GCS to an external center to coordinate the whole mission (receiving all the telemetry and

[1]5GCity is a coordinated national project (2017-2019), funded by the Spanish Ministry of Economy and Competitiveness with the following partners: Universidad Carlos III de Madrid, Universidad de Granada, Fundacion i2Cat, Universitat Politecnica de Catalunya, Universidad de Vigo and Universidad del Pais Vasco.

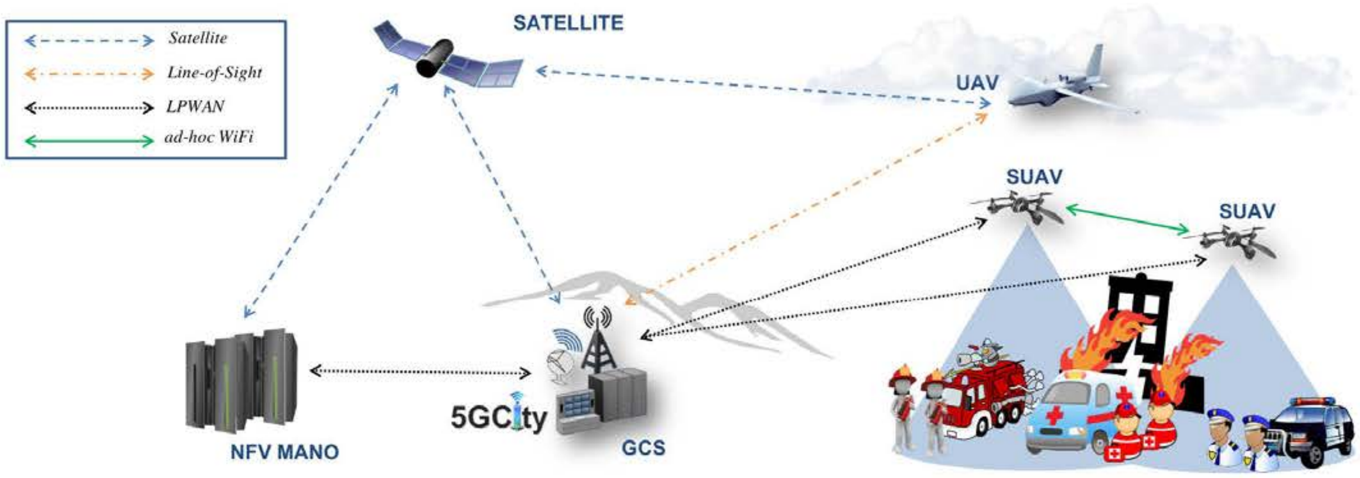

Fig. 1. SUAV network supporting emergency services.

from the SUAVs, orchestrate the different services, etc.) can be enabled by means of a satellite communication or through a tactical UAV (we have already presented some experiences using the SIVA, a Spanish UAV that belongs to the INTA[2] in [6]). In addition, this information will also be available to the different network participants involved in the emergency services.

In order to provide this general scenario, we consider four key technologies which are essential to accomplish our goals:

- **Sofware Define Networking** (SDN): the SUAV network is limited in communication resources. Network nodes are not static and are also battery-limited which bring constant changes in network topology. In addition, nodes behavior changes significantly depending on the application. Therefore, legacy routing protocols designed for MANETS does not address the special characteristics of UAV networks. In those scenarios, the use of SDN [7] can help in path and channel selection. SDN controller has a global view of the network and it has the possibility to route traffic in different paths if a situation makes it necessary (i.e. busy links or link failure). However, the use of a centralized controller has a significant cost. A control channel has to be maintained over time, which implies an increment in battery consumption. Exploring the possibilities of this control channel is one of the main purposes of the use case (LTE, LoRA, satellite link, etc.).

- **Data Distribution Service** (DDS): in combination with multicast, the Object Management Group (OMG) DDS standard [8] provides an scalable and effective middle-ware publish/subscribe technology that allows information dissemination over network participants. DDS subscriptions are content-based enabling a plug and play architecture with dynamic discovery which brings interoperability between SUAVs deployments. In addition, DDS implements QoS policies to control several properties such as real-time delivery, bandwidth or redundancy. However, the deployment of multicast routing protocols is not desirable while working with small resources devices (i.e. Single Board Computers).

- **Network Function Virtualization** (NFV): the use of NFV [9] management and orchestration (MANO), allows fast deployment of Virtual Network Functions (VNF). NFV simplifies the deployment of new services, reducing significantly cost associated with hardware. Thus, any VNF can be deployed in any SUAV dynamically, changing its role depending of the network necessity. However, since SUAVs payload are limited-resources devices, installing virtual machines is an expensive process. For this purpose, we are considering its deployment based on containers (small lightweight pieces of software that includes everything needed to run it).

- **Signal Initiation Protocol** (SIP): to create, modify, and terminate multimedia sessions we use the application-layer protocol SIP [10]. SIP provides several solutions when establishing communications such as user location, user availability or user capabilities. However, SIP is not integrated in standard communications and is limited to specific solutions implementing the protocol requiring additional services to be installed in the system.

III. Scenario validation

The validation of our scenario to support service deployment is divided into three different stages. In the first one, we conduct several basic tests and validate the solution with an integration with 5TONIC[3] laboratory. In the second stage, we perform an exhaustive analysis to select the most appropriate technology for the control channel. Finally, to complete the validation, we deploy a real environment use case to confirm the correct performance of the proposed solution.

[2]INTA: http://www.inta.es/

[3]5TONIC: https://www.5tonic.org

A. First scenario validation

In the first part of the validation, we are developing a testbed leveraging real equipment. Figure 2 illustrates the principal components comprising the tested where the role of the SUAV is implemented by the commercial model Parrot AR Drone 2.0[4]. This model allows to carry Single Boards Computers (SBCs) as payload, adding computation capacity to the SUAV. The Raspberry Pi model 3B[5] is the one selected in our scenario to act as SBC. These devices present a reduced cost and can provide different wireless communication despite of their limited capacity. We have previously investigated the deployability of VoIP services over SBCs in [11]. Results show that throughput, RTT, and jitter meet the minimum requirements to ensure QoE when deploying a multimedia service.

In the preliminary tests, each SUAV has two wireless channels. The first one, dedicated to the Data Plane (DP), is an ad-hoc WiFi network which allows not only mobility but also a fast network reconfiguration. On the other hand, a SUAV acts as WiFi AP if an active user is near the coverage area. For this purpose, we use an infrastructure based WiFi network in 2.4 GHz. Note that, at this stage of our work, the communications with the GCS are wired. However, the incorporation of a wireless control channel will be contemplated in the second stage.

As we have already pointed out, the GCS is responsible for traffic routing. Because of the SUAV networks nature, it is believed that current algorithms designed for MANETS do not address the particular characteristics of this type of networks. For this reason, we are considering the use of an SDN MANET [12] where the advantages of the Device to Device (D2D) networks and the flexibility of a centralized network are maintained. SDN allows to balance network load and provide a reconfigurable network, tolerant to link failures. To carry out the SDN MANET we will have an SDN controller installed in the GCS. At the same time, all the SBCs will run Open vSwitch [6] which allows the use of OpenFlow protocol, considered almost a standard protocol for SDN.

Finally, to validate the agile deployment of network services over a cloud platform offered by a dynamic swarm of SUAV equipment, we will perform a joint experiment between the Universidad Carlos III de Madrid and 5TONIC laboratory. Accordingly, 5TONIC is an open research and innovation laboratory founded by Telefonica and IMDEA Networks based in IMDEA Networks (Madrid), which objective is to create a global open environment where members from industry and academia work together in specific research and innovation projects related to 5G technologies. 5TONIC functional production-like MANO environment will orchestrate the network services deployment into the different SUAVs. Communication among the GCS and 5TONIC lab take place over an optical laser link between Universidad Carlos III de Madrid and IMDEA Networks. Although 5G communications are normally considered as wireless, the integration of wireless connections and back-haul networks is needed to allow a fast and robust service deployment.

[4]AR Drone 2.0: https://www.parrot.com/es/drones/parrot-ardrone-20-elite-edition#parrot-ardrone-20-elite-edition-details

[5]Raspberry Pi 3 B: https://www.raspberrypi.org/products/raspberry-pi-3-model-b/

[6]Open vSwitch: https://www.openvswitch.org/

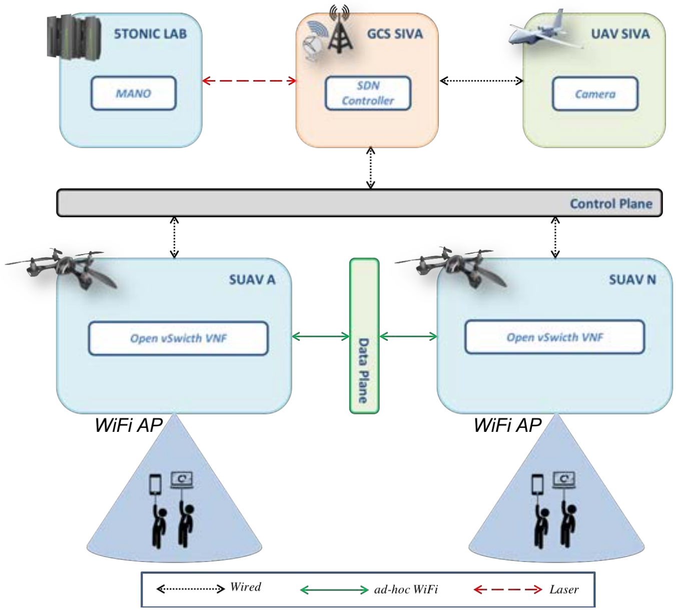

Fig. 2. Validation Testbed.

B. Control channel validation

In the second stage, all the SUAVs will have a wireless control channel directly connected to the GCS which will be mainly used by the SDN deployment but that can also be used for additional purposes. This control network will be organized in a star (one hop) topology. To provide a robust and stable control channel, different low-power wide area networks (LPWAN) alternatives are under analysis such as LTE, LoRaWAN, Weightless W or SigFox. LPWAN offers long range communication without huge power consumption, even so, the data rate offered by some of these proposed alternatives is really limited and should be carefully analyzed. Thus, depending on traffic load traversing the links among the GCS and SUAVs once the first stage is accomplished, we will select the most appropriate technology.

C. Real scenario validation

After the first two stages, the main goal is the validation of the whole scenario in a real environment. In the last years, Smart Cities are being deployed as platforms where companies and institutions are able to trial innovative deployments in a real-world testbeds more than just inside a laboratory scenario. For that purpose, we plan to use the i2cat institution infrastructure (as 5GCity partner), a public lighting infrastructure where the lamppost forms a Smart Grid integrating the hardware and the IP services software deployed in the network. The intended use case will allow SUAVs to fly into the lightning infrastructure area and use them as communication alternative towards the external coordination center.

IV. Conclusions and Future Work

This article has presented one of the use cases that will be developed inside the context of the 5GCity project. The enormous potential of UAV networks and in particular, the use of SUAVs, which can be placed in geographical areas and scenarios that are not accessible by legacy emergency services, is presenting them as the perfect candidates to hold embedded devices like SBCs, that are capable of deploying a variety of new services into the Smart Cities. After a previous analysis, it seems clear that for a correct operation a virtualization deployment based on NFV and SDN is needed. In the paper, we also present the research lines associated with this article and all the future work that will be done in 5GCity to accomplish a good performance such as the selection of the communication channels and the deployment on a real environment.

ACKNOWLEDGEMENTS

This article has been partially supported by the 5G-City project (TEC2016-76795-C6-3-R) funded by the Spanish Ministry of Economy and Competitiveness.

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