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UAV based 5G Wireless Networks: A Practical Solution for Emergency Communications

Yuan Gao(1), Jiang Cao* (1), Ping Wang (1) ,Jing Wang(1) ,Ming Zhao(2) ,Shaochi Cheng(1) ,Su Hu(3) , Weidang Lu(4)
(1) Academy of Military Science of the PLA, 100091,China
(2) Beijing National Research Center for Information Science and Technology (BNRist),
Tsinghua University, Beijing, 100084, China
(3)University of Electronic Science and Technology of China, Sichuan, 610054, China
(4) Zhejiang University of Technology, Zhejiang, 310014, China

Abstract

Wireless personal communication has become necessary part of our daily life. Network operators have established many 5G base stations for most residential areas, but the untraversed area such as sea, desert, high attitude area, etc. could not benefit from the high quality wireless personal communication technology, especially for the emergency use. In this work, we provide a solution for emergency use in untraversed area, based on the Unmanned Aerial Vehicle (UAV) platform, 5G could extend the service area to most areas all over the world when necessary without establishing ground based stations, providing satisfied QoS and stability.

1 Introduction

5G has become the most popular wireless communication technology recently[1], compared to 4G and previous systems, the advances in speed, latency and reliability are greatly improved. Relying on the densely-deployed base stations, number of UEs that connected to gNodeB decreased, so the unit resources for attached UEs are improved, it is one key improvement in 5G. However, the coverage of 5G is still insufficient all over the world, network operators build the 5G base stations only in some hot zones, so some untraversed area such as sea, desert, mountain, etc. Current 5G solution could not solve the problem of coverage in such areas. To ensure the QoS, 5G base stations must be established in such areas but it is clear that network operators will not interested in such expensive behaviors.

Considering the demand of coverage in untraversed areas, 3GPP has begun the standardization process of non-terrestrial deployment of 5G, e.g. the satellite and UAV based 5G. The satellite based 5G is the simple and effective way to tackle the coverage problem, especially when the price of low orbit satellite continues to reduce. There are many satellite based discussions and solutions in academic and industry. In [2] and [3], general discussions about satellite based 5G network are listed, the advantages and pending open problems also discussed in these works. In [4], the discussion based on 3GPP release 15 is given, however, the latest release 17 still leaves the non-terrestrial 5G network as an open problem. In [5], satellite MIMO for 5G is discussed, where MIMO is the possible technology to improve the downlink speed when speed of relative movement is very high, moreover, the distance between satellite and user is too long for uplink transmission using traditional mobile terminals. In [6] and [7], the evaluation for 5G NR satellite physical layer is given, weaknesses in space based 5G are discussed based on 3GPP release 15. In [8][9], concept of antenna design in 5G satellite systems is discussed, however, the relative speed is still hard to be solved.

It is clear that the satellite based 5G can effectively provide coverage but the difficulty is the performance. Along with the rapid development of UAV, it could loiters longer and carry heavier payload, which may become the possible solution of emergency communication method using 5G. But the standardization of 5G UAV network remain uncertain in the upcoming specifications. Thus, in this paper, we discuss the UAV based 5G wireless network in emergency communication scenario. In part 2, the architecture of 5G UAV network is given, the key problem of wireless backhaul, UAV based core network and gNodeB, enhanced wireless terminals are discussed. In part 3, we present the remaining challenges of 5G UAV wireless networks. Conclusion is drawn in the last part.

2 UAV based 5G Network

UAV has become candidate of non-terrestrial 5G network because of the flexibility and better performance. In this part, the architecture and solution are discussed in detail, core network, base station, terminal, backhaul are introduced separately. In addition, the control of UAV is also mentioned, especially how to control the speed, height and route.

In figure 1, we elaborate the architecture of 5G UAV networks. First of all, the UAV is not the traditional rotor craft but the fixed-wing craft, generally speaking, such UAV is strong enough to load 5G base stations and other necessary equipment, in addition, provide adequate steady electricity. Second, low orbit satellite is still indispensable to provide control signaling of UAV and necessary backbone link to network operators. Third, uplink from ground UE to UAV (or directly to satellite 5G) is the constraint problem because of the power limitation.

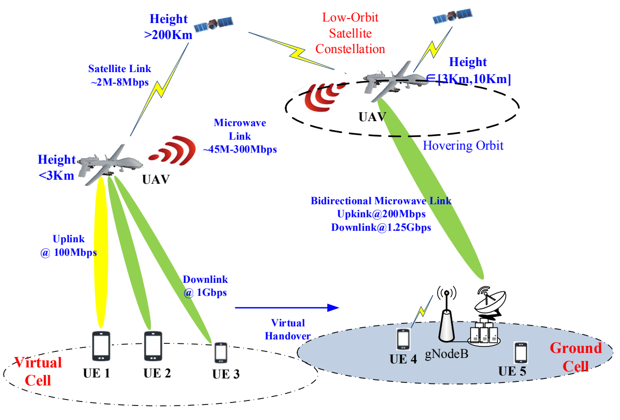

Figure 1. UAV 5G Network Architecture. Low Orbit Satellite and UAV served in different region.

Typically, UAV works within the height of 10Km at a speed of no more than 400Km/h, we suggest that the 5G base station (generally called gNodeB) and core network installed together on board, this is the effective way to avoid the interface problem between gNodeB and core network. To provide cooperative link between gNodeBs, a microwave link between UAVs is also a possible option. For an operation mode where a group of highly coordinated UAVs to complete orderly flight, it would be quite challenging and inefficient to connect each individual UAV directly to the ground cellular base stations. However, the current technology implementation has not guaranteed reliable UAV-to-UAV communications to form aerial network by the UAVs with or without assistance of cellular base stations. Thus, more efforts are needed to devote to UAV-to-UAV communications with or without cellular assistance. To receive signal from satellite working at low orbit (about 200Km Height), a satellite transceiver is also installed.

2.1 Backhaul

The backhaul discussed in this work is mainly focused on the wireless link from UAV to satellite relay or to network operator. Joint design of gNodeB and small scale core network could effectively reduce the transmission delay, but there must be some information that need to be exchanged from UAV to cloud based core network, e.g. the cross domain calling, the licensing, interregional access. The difficulty is clearly the wireless bandwidth and the transmission delay.

Wireless backhaul links are vulnerable to blockage, e.g., due to moving UAV, or due to the ground UE with infrastructure changes (new buildings, trees or cars). Also, traffic variations can create uneven load distribution on wireless backhaul links leading to local link or node congestion. Topology adaptation refers to procedures that autonomously reconfigure the backhaul network under circumstances such as blockage or local congestion without discontinuing services for UEs. So the minimum bandwidth to support 5G wireless backhaul must be provided to ensure the integrity.

2.2 UAV

In our solution, gNodeB and small scale core network are both installed on board, so the UAV could working individually within its coverage and support most of the 5G function such as registration, resource allocation, etc. If the wireless backhaul is invalid, the 5G UAV system could serve the UEs in offline mode, just like the local area network. There are two possible working mode for UAV 5G systems as illustrated in figure 1. First, UAV serve as gNodeB and provide downlink speed of 1Gbps to ground UEs at the height of no more than 3KM. The UAV may provide a virtual cell along with the move of UAVs, the UEs attached to the UAV can receive or transmit information from UAV. This is suitable for the emergency scenario in untraversed area such as desert and forest area. Second, UAV is working as wireless relay, the ground gNodeB is combined with a Ground-to-air Communication Link, the bound for uplink is about 200Mbps and downlink at 1.25Gbps according to the state of art. Then the gNodeB is working as the traditional ground cell to serve UEs within its coverage. This scenario is suitable for ship-based 5G networks, the gNodeB is installed on ship and UAV provide the relay link, the ship-based 5G gNodeB could serve UEs on board and IoT nodes all over the ship, enjoying the performance of 5G.

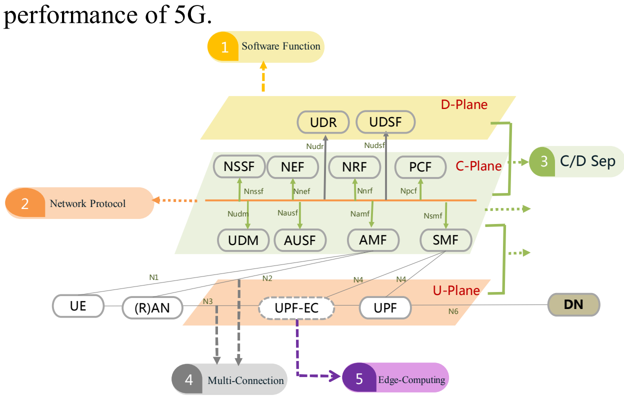

Figure 2. UAV embebbed small scale core network.

In figure 2, the small scale UAV 5G core network is given. By extending the SBA（Service-based architecture） to 5G UAV networks, the service-based network architecture draws on the design concept of "microservices" in 5G and defines network functions as multiple relatively independent service modules that can be flexibly called. Based on this architecture design concept, operators can flexibly adapt to new business requirements. Add or upgrade network element functions to achieve flexible customized networking.

The overall goals of the 5G UAV network are driven by data traffic. Not only the access network architecture and physical layer technology, but the core network architecture is more in line with the organic combination of the microservice concept and the virtualization of network element functions. Functions or services provided are reorganized to suit different business needs. Each network element can contain multiple network service instances. Such a framework design not only conforms to the respective functional logic and appears independently in the form of microservices, but also enables the network segmentation process designed to target differentiated services. Organic adaptation and orchestration. The services corresponding to each specific network segmentation are in the form of network element function segmentation instances. Corresponding to the target services in the 5G system, eMBB, URLLC, etc., the Single Network Slice Selection Assistance Information (S-NSSAI) can tell the network what specific types of services are, so that the network can provide customized services based on different service characteristics. Different target service types can be assigned different network segmentation identities, and different UE groups involved in the same type of service can also be assigned different network segmentation identities. Of course, the network can also allocate multiple network segmentation identities to a UE at the same time. It indicates that the number of configurations needs to meet the maximum number of network segmentation instances allowed by the default configuration of the access network, or the number is further limited by the NSSF function.

2.3 Terminals

The 5G UAV network will require a special designed handheld terminal to provide enough uplink power. In [10], according to the previous field trial results, the Huawei Mate 30 with the uplink power of 0.2 watt could only gain the speed of 8.4Mbps to the UAV site, which is not acceptable for many multimedia data traffic. In emergency communication, the demand to enhance the uplink power is feasible, such as the satellite terminal, traditional commercial used terminals could work at the power level of 2 watt. In this way, if we could increase the uplink power to 2 watt, the uplink speed at the same conditional could be increased to 50Mbps with the help of MIMO diversity and enhanced decoding scheme at the UAV side.

3 Challenges

The UAV 5G is still an open problem and pending to be discussed in the future standardization. So the utilization will meet many unknown and thorny problems.
Base on the analysis of mobility issues in the above section, the fluctuated antenna gain and frequent deep fading due to side lobes of the gNodeB antenna is the key reason for long interruption time caused by handover and RLF. The straightforward way is to improve the aerial coverage performance of antenna side lobes or introduce additional antenna which directions are to the air. However, this demands upgrade or replace the existing hardware, such as deploying dedicated gNodeB for drones or Massive MIMO antenna to provide special beams pointing to aerial objects, which has to cost large expense for equipment and constructions. When the UAV group flies according to a certain trajectory, the cellular network on the ground needs to provide communication services to ensure that the UAV can safely fly to the destination. Since the cellular network provides network coverage for traditional terrestrial users, when it provides network coverage for the UAV, the original model is no longer applicable, and a new model needs to be established for analysis.

4 Conclusion

In this work, we discuss a UAV based 5G wireless network architecture, the analysis of the proposed method is given in detail, containing the UAV gNodeB, small scale core network, enhanced terminal and wireless backhaul. Also the challenges about handover and coverage are discussed in this work in general.

5 Acknowledgements

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