Industry Research and Standardization Progress in Cellular Communication Solution for Unmanned Aerial Vehicle Application

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Abstract. Unmanned Aerial Vehicles have been widely used in many scenarios, and several kinds of wireless communication methods are adopted for UAV monitoring and remote control, e.g. satellite communication, WiFi communication and cellular communication. During the wireless communication solutions mentioned above cellular method is considered as a potentially dominant solution due to the wide deployment and low cost advantage. In this paper we present the latest industry research and standardization progress in cellular communication solution for UAV application from 3GPP. Two technical issues are observed, i.e. high neighbour cell interference and frequent handover, and based on the analysis three kinds of enhancement for current cellular network are proposed, i.e. flight path information reporting, virtual cell solution and dedicated base station.

Keywords: UAV · Neighbour cell interference · Cell fragmentation

1 Introduction

Small UAVs, also called drones, and other low altitude aircrafts, have many current or future applications, including network tower inspection, search and rescue, small package delivery, mapping and surveying, etc. During these applications, the data types for transmission are telemetry data, command and control data, application data [1]. Telemetry refers to data from the UAV reporting various status messages and sensor results. Examples are position, velocity/airspeed, attitude and heading, fuel/power status, communication link quality, etc. For command and control, two-way links that enable sending commands to the drones and receiving responses are required. This data link supports messages such as navigation commands, waypoint entry, configuration adjustments, information requests and safety commands. Application data usually refer to image data or video data especially for inspection and mapping applications.

Considering the requirements of wireless communications, telemetry data, command and control data need high reliable links both for uplink and downlink, and image and video data need high speed uplink link.

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In 3GPP the study item on enhanced support of aerial vehicles began in March 2017 and the first version of release, i.e. Rel-15, including UAV feature was frozen in September 2018.

The 3GPP working group considers adopting the requirements listed in the following table for the connectivity services for UAV [2] (Table 1).

Table 1. Requirements of connectivity services for UAV.

Requirement items	Value
Data type	Command and Control (C&C) This includes telemetry, waypoint update for autonomous UAV operation, real time piloting, identity, flight authorization, navigation database update, etc. Application data This includes video (streaming), images, other sensors data, etc.
Heights	Target up to 300 m AGL
Speeds	Horizontal: up to 160 km/h for all the scenarios (Urban, Rural)
Latency	C&C: 50 ms (one way from eNB to UAV) Application data: similar to LTE UE (ground user)
DL/UL data rate	C&C: [60–100] kbps for UL/DL Application data: up to 50 Mbps for UL
C&C reliability	Up to 10-3 Packet Error Loss Rate

Aiming to fulfill the requirements above, some research work has been done to identify the issues which exist in current cellular network and several candidate solutions have been proposed to solve them.

The following sections are organized as follows, Sect. 2 presents the identified issues in cellular network performance, and several candidate solutions are provided in Sect. 3, we conclude the paper in Sect. 4.

2 Technical Issue

2.1 High Neighbour Cell Inference

In the intra-frequency network deployment UEs often suffer from intra-frequency interference from neighbour cells, especially for UE in cell edges. For UAVs flying at a relatively high altitude above base stations they will “see” more base stations than that on the ground, and at the same time they can receive more downlink signals from these base stations, which means more downlink interference. Besides of more interfering neighbour cell, another factor that influence signal strength is side lobes. Current cellular network are focused on terrestrial user equipments, and the antennas are usually down tilted to adjust the main lobes to aim to ground users. When the UAV flies at a high altitude, the serving lobe of the serving antenna changes from main lobe to side lobe illustrated as the following figure [3]. In this case the antenna gain provided by side lobe is reduced heavily compared to that from main lobe. So when the signal strength from serving cell decreases and the interference comes from more neighbour cells, the downlink neighbour cell interference is more severe for UAVs than UEs on ground (Fig. 1).

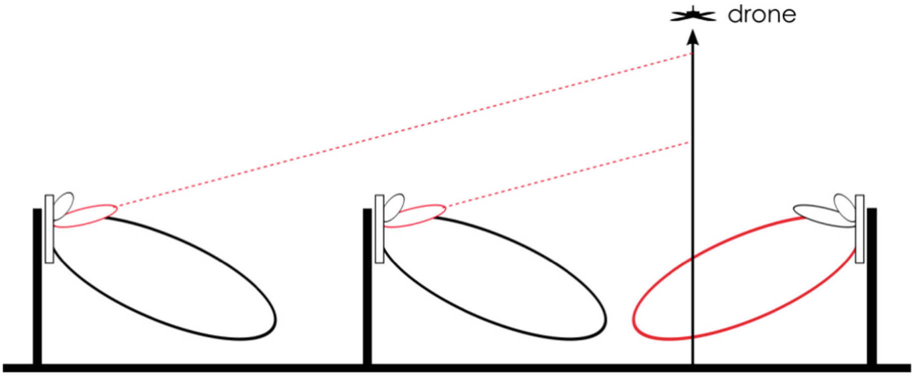


Fig. 1. Serving lobe changes from main lobe to side lobe when UAV's height increases.

Some simulation results related to downlink coupling loss and SINR are also provided in [4] as follows (Figs. 2 and 3).

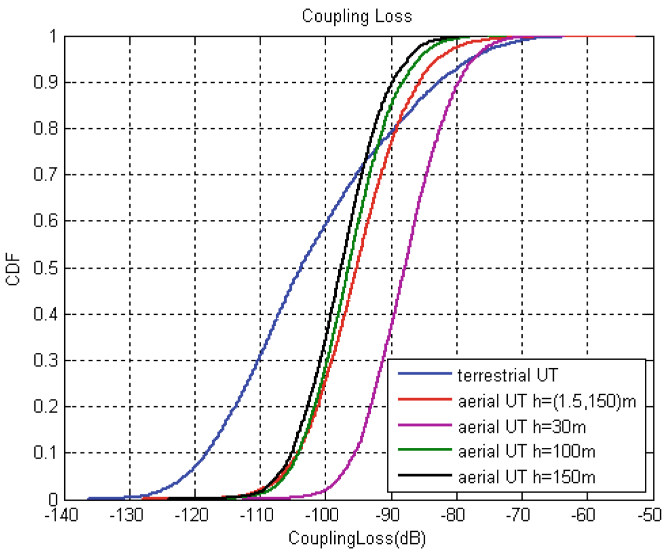


Fig. 2. Coupling loss comparison between terrestrial UE and aerial UE.

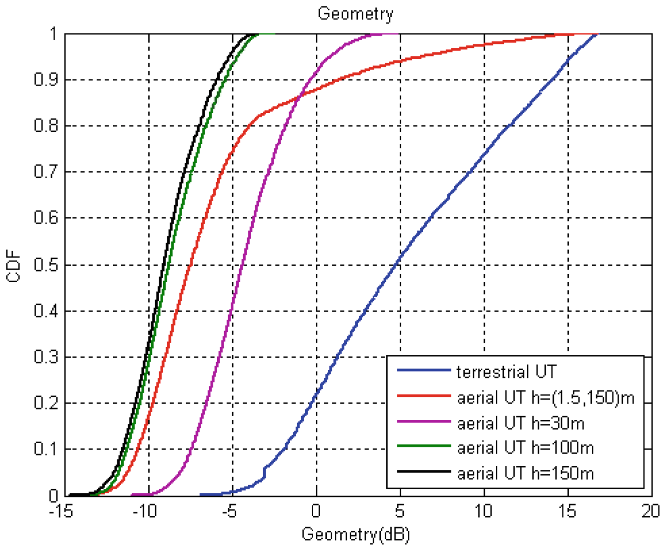


Fig. 3. SINR comparison between terrestrial UE and aerial UE.

2.2 Frequent Handover

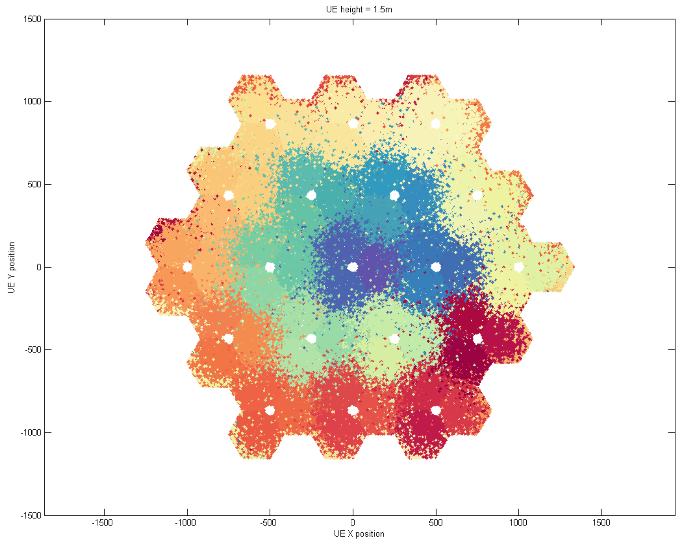
When the UAV flies from ground up to sky, the serving lobe changes from main lobe to side lobe of base station antenna, one impact is that the serving signal strength is weaken than usual so that the downlink SINR is reduced and the UE has to experience a bad wireless link. The other impact is that because the aerial coverage is fragmented compared to terrestrial coverage, the more frequent handover may occur which leads to more interruption time to execute handover.

Some simulation results of cell fragmentation have been provided in [5], from the figures below, we can see that as the UE height increases from 1.5 m to 300 m, the fragmentation of aerial coverage becomes worse, i.e. in case of 300 m height the aerial coverage is not continuous anymore (Fig. 4).

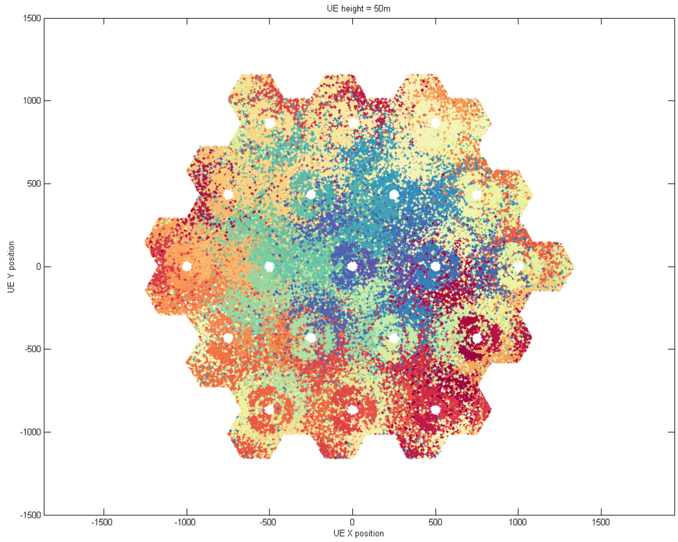
The simulation results of handover rate also demonstrate that the handover occurs twice as much as that on the ground [5] (Fig. 5).

In the field test for UAV communication performance, it also shows that there are much more handover at a relatively larger height, i.e. at most 27 times more than that on the ground [6]. At the same time more handover failure are observed (Fig. 6).

From the simulation results above, we can see that due to the fragmented aerial coverage, more handover occurs and the failure rate of handover also increases, consequently UE may experience a bad aerial circumstance. Some effects can be foreseen such as longer interruption time due to handover, even much longer service interruption due to connectivity reestablishment after handover failure.

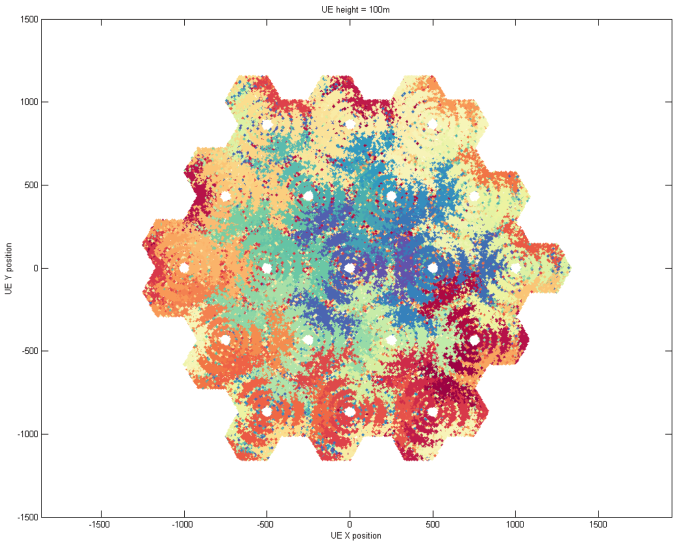


(a). Cell coverage at 1.5m height.

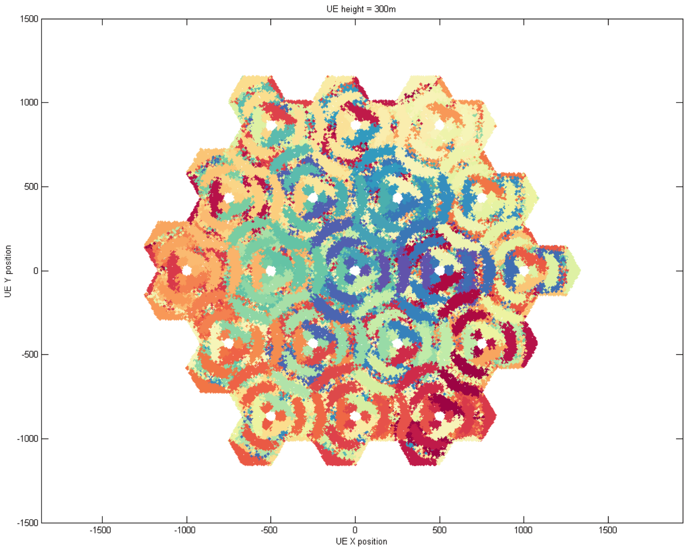


(b). Cell coverage at 50m height.

Fig. 4. Cell coverage variation in different heights.



(c). Cell coverage at 100m height.



(d). Cell coverage at 300m height.

Fig. 4. (*continued*)

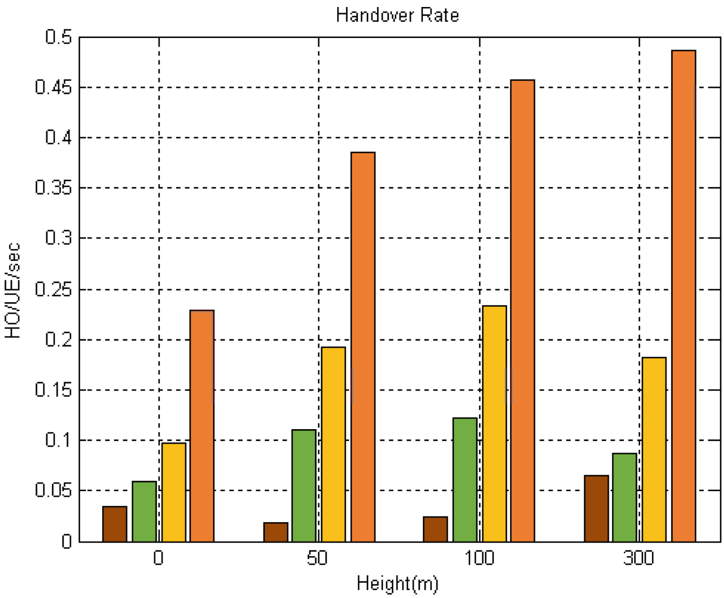


Fig. 5. Comparison of handover results in different height.

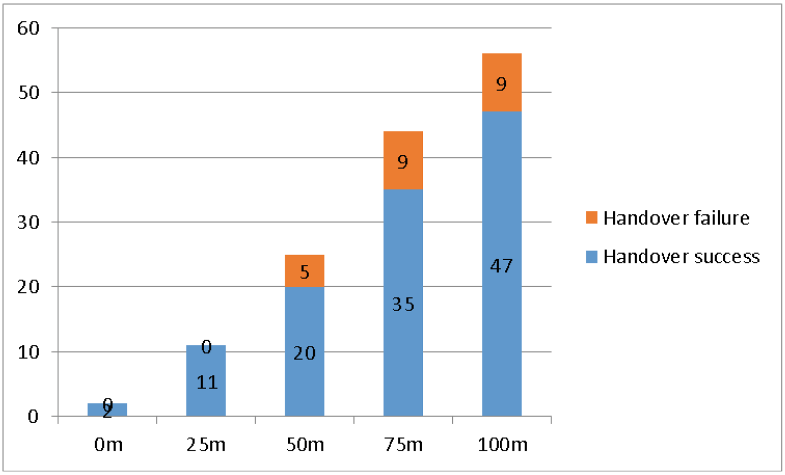


Fig. 6. Field test result of handover success and failure.

3 Candidate Solutions

3.1 Flight Path Information Reporting

A drone is a specific UE which can fly automatically or under control, it means a drone can know the flying path information before the flight, e.g. 3D flying direction, critical midway location and 3D velocity. And usually a drone has positioning ability and it can report location information including altitude information. Flying path information is helpful to assist serving eNB to select suitable target eNB during HO for aerial UE. For example, according to aerial UE's flying path, eNB can avoid aerial UE handover to a cell that it will have a short connection period. This is depicted in the following figure [7] (Fig. 7).

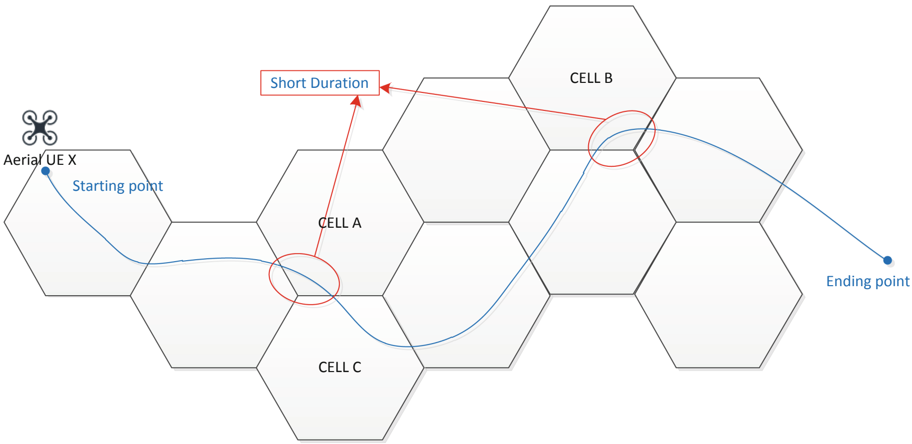


Fig. 7. Handover decision according to flight path.

From the above figure, it can be seen that aerial UE will have short flying duration in Cell A and Cell B. Thus when doing handover, such kind of cell can be skipped so that the handover can be less frequently and can avoid unnecessary handover failure. This flight path information reporting mechanism has been specified in Rel-15 LTE.

3.2 Virtual Cell

Following the concept of cell coordination, a reserved DL resource can be allocated for drones, and the corresponding downlink data and demodulation reference signal can be jointly transmitted by multiple eNBs. As this reserved resource is specific for drones, it is named as Virtual Drone Cell (VDC) [8]. As a VDC is the composition of several neighbour cells, the VDC has a more large coverage area, so the handover rate can be declined. And this solution also changes interference from the neighbour cells into useful signals, the DL SINR can be improved obviously. This solution has been discussed in 3GPP, due to potential deployment complexity some other enhancements may be considered (Fig. 8).

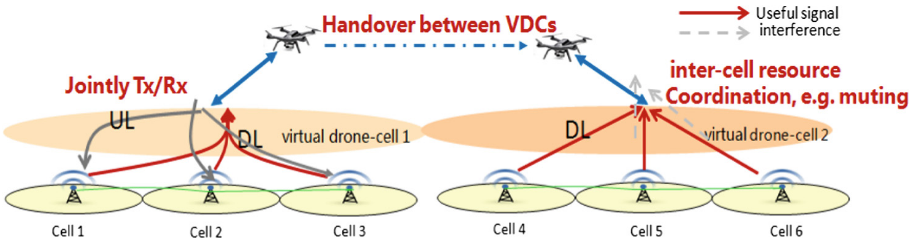


Fig. 8. Virtual Drone Cell.

3.3 Dedicated Base Station

Another solution is that the base station is a dedicated only for drones, which has a specific antenna elevation angle to serve flying UEs above an altitude as illustrated in Fig. 9. So a drone UE is supposed to be served by theses dedicated eNBs for better signal quality [9]. but there are still some technical issues that need to be done further, e.g. signal interference with satellite communications in the same frequency band.

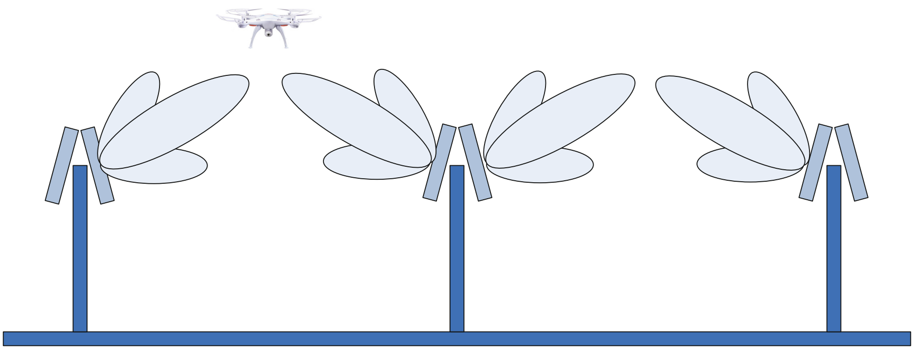


Fig. 9. Dedicated UAV base stations.

4 Conclusion

UAVs have many current or future applications, but current cellular network cannot support UAV type UE perfectly. Some technical issues have been identified in 3GPP, e.g. high neighbour cell interference and frequent handover, and several candidate solutions have been proposed to solve the problems. One of them, i.e. flight path information reporting has been specified in 3GPP Rel-15, other solutions such as virtual drone cell and dedicated base station still need further study.

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