A Study on Switching between Aerial Systems with UxNB Functionality

JungSook Bae, Hyun Lee, Heesoo Lee
Terrestrial & Non-Terrestrial Integrated Telecommunications Research Laboratory
Electronics and Telecommunications Research Institute
Daejeon, Republic of Korea
{jsbae, hyunlee, heelee}@etri.re.kr

***Abstract*— The UxNB, the Uncrewed Areal Vehicle (UAV) with on-board base station, is emerging as a means of easily providing communication services to disaster areas that do not have or lack communication infrastructure or require temporary coverage for mobile users and hots-spot events. However, with the short UAV operation time of 15-20 minutes due to battery limitations, it is difficult to provide long-term communication services. In order to provide continuous mobile communication services in the service area, the UxNB switching is required, allowing the deployment of new UxNBs with high battery power to replace the existing UxNBs. In this paper, we present the UxNB-based temporary communication infrastructure and UxNB switching procedures and techniques for maintaining 5G cell coverage for ground User Equipment (UE)s in the infrastructure.**

Keywords—UxNB, UxNB-based temporary 5G communication infrastructure, UxNB switching

I. Introduction

UAVs operate at low altitude of less than 1.5km and can fly autonomously, so they are used in various vertical applications such as delivery, communication emergency network construction, disaster monitoring, and reconnaissance.

Especially in the field of wireless communication, the UAV has attracted interest due to ease of deployment, low acquisition and maintenance costs, high-manoeuvrability and the ability to hover in a 3D air space. The UxNB, the UAV with on-board base station, is emerging as a means of easily providing communication services to disaster areas that do not have or lack communication infrastructure or require temporary coverage for mobile users and hots-spot events. [1].

Since the UxNB operated in the 3D air environment transmits and receives wireless signals in the air, it is less likely to suffer communication failures due to obstacles on the communication path. And it can provide wide cell coverage compared to base stations installed on the ground. However, with the short UAV operation times of 15-20 minutes due to battery limitations, it is difficult to provide long-term communication services. In order to provide continuous mobile communication services in the service area, the UxNB switching is required, allowing the deployment of the new UxNBs with high battery power to replace the existing UxNB.

In the efficient UxNB switching procedure, techniques should be considered to provide continuous services to ground mobile communication users and to prevent signaling storms caused by simultaneous handover by a large number of ground mobile communication users to the new UxNB.

In this paper, we present the UxNB-based temporary communication infrastructure consisting of the UxNB, the A2G mobile backhaul, and the UxNB-based temporary network management system to provide 5G mobile communication services. UxNB switching procedures and techniques for maintaining 5G cell coverage for ground UEs are presented in the infrastructure.

The rest of this paper is organized as follows. In Section II, we describe the configuration and the logical structure of UxNB-based temporary 5G communication infrastructure. Section III presents the procedures and techniques for the UxNB switching and features required for UxNB operations on the 5G System(5GS). Finally, we conclude this paper in Section IV.

II. UxNB-based Temporary 5G communication infrastructure

A. Configuration

Figure 1 shows the communication infrastructure that provides a temporary 5G networks based on the UxNB in areas where communication infrastructure is not available or scarce. It consists of the UxNB, the UAV with a base station function, the A2G wireless backhaul connecting the UxNB and the ground 5G Core network (5GC), and the UxNB-based temporary network management system (UTNMS).

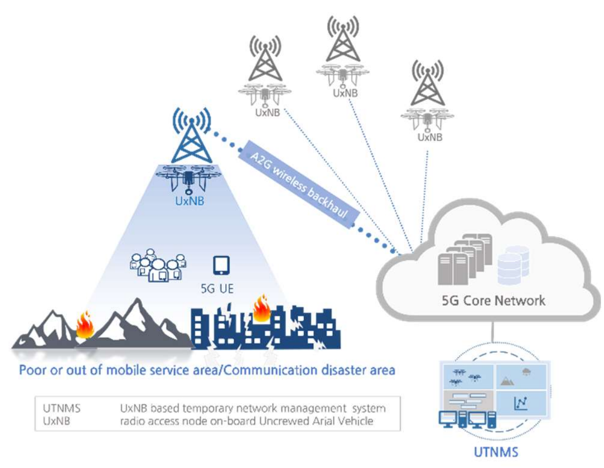

Fig. 1. UxNB-based temporary 5G communication infrastructure

Depending on the range of the service area, several UxNBs may operate to form 5G cell coverage.

The UAV in the role of the UxNB accommodates both the functions of 5G UE and Next Generation-Radio Access Network (NG-RAN) defined in [2] for automated operations and managements through 5GS.

Considering the nature of the UxNB that can be deployed in various inaccessible environments, the A2G wireless backhaul should support the long-distance communication between the area where the UxNB is deployed and the 5GC connection point and accommodate the 5G gNB transmission capacity.

UTNMS provides identification, authentication, authorization, and operation management services for UAVs deployed in the 5G temporary networks, and UxNB operation status management services.

B. Logical structure

The logical structure of the 5GS for the UxNB management is shown in Figure 2.

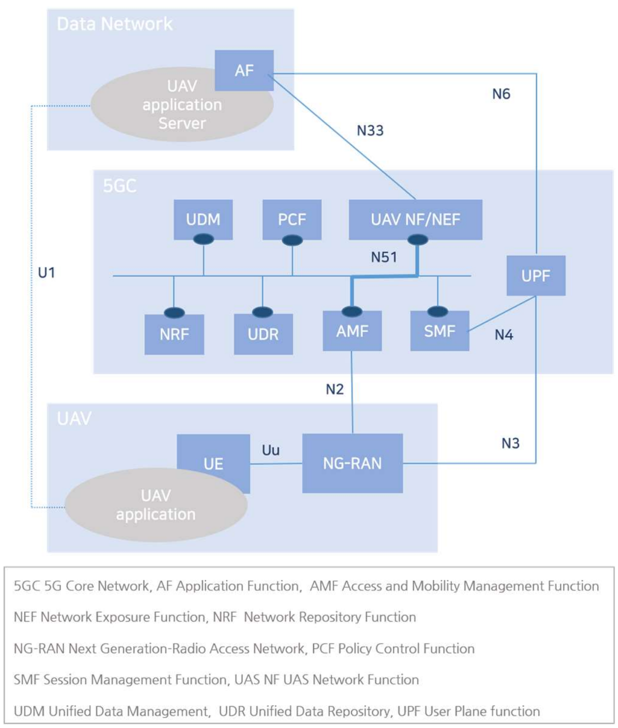

Fig. 2. 5G system logical structure for the UAV management[2]

In addition to the 5GC functional entities defined in [2], the UAV Network Function (NF) functional entity is defined for the UAV management.

The UAV NF is supported by the Network Exposure function (NEF) and used for external exposure of services to the UAV application server. A dedicated NEF may be deployed to provide only the UAV NF functionality, i.e. to support the UAV specific features/APIs and the NEF features/APIs that are specified for capability exposure towards the UAV application server.

The Application Function (AF) entity is located at the UAV application server and interact with UAV NF to provide UAV management services to the UAV.

III. UXNB SWITCHING

A. Procedure

The UAV with a limited power source has power below a certain threshold, ends its mission at the deployed location, and automatically returns to its original position.

If the remaining power of the deployed UAV approaches the return power threshold and needs to be maintained for temporary coverage generated by UxNB, a procedure is needed so that a new UxNB with sufficient power can take over the role of forming communication coverage.

In the UxNB-based temporary 5G communication infrastructure structure presented in Section 2, the UxNB switching for maintaining 5G communication coverage is performed in the following procedure. For the operation management of UAVs by the UTNMS, it is assumed that the procedure described in [2] for UAVs placed in the service area to register with the UTNMS via the 5GC

- Step 1: The old UAV informs the UTNMS that the battery level has reached the return threshold.
- Step 2: The UTNMS decides the deployment of the new UxNBs in the service area and controls the new UAV to move to the adjacent location of the old UAV deployment area.
- Step 3: The new UAV sets up the A2G mobile backhaul link and turns on the UxNB function
- Step 4: The new UxNB establishes a connection to the Access and Management Function (AMF) of the 5GC via the A2G mobile backhaul and acquires the authorization for operations.
- Step 5: By reflecting the trend of mobile user handovers over a certain period of time, the UTNMS controls the location of new UAVs to move to the location of the old UAV while controlling the reduction of transmission power of old UxNB and the increase in transmission power of new UxNB.
- Step 6: While repeating step 5, if there is no connected mobile communication users, the old UxNB turns off the UxNB power, releases the A2G mobile backhaul link, and moves to the return destination.

Step 5 of the procedure of UxNB switching prevents signaling storms following simultaneous handover of multiple ground mobile users to new UxNBs while maintaining continuous communication coverage for ground mobile users.

Figure 3 illustrates the step 5 of the UxNB switching procedure. More detailed operations of step 5 are as follows.

- Step 5-1: The new UxNB, which will replace the old UxNB under the control of the UTMNS, moves into the air at the position D away from the current the UxNB position. The distance D is determined by the UTNMS as a value for accommodating the γ% ground UE of the cell edge formed by the old UxNB.
- Step 5-2: The new UxNB constructs the cell with the transmission power *NT*.
- Step 5-3: The AMF-controlled N2 handover is performed from the old UxNB to the new UxNB for UEs in the cell overlapping area.
- Step 5-4: After the handover of all UEs in the overlapping area to the new UxNB is completed, the AMF delivers it to the NEF so that the NTNMS recognizes it.
- Step 5-5: The NTNMS controls the old UXNB's transmission power reduction, the new UxNB's

transmission power increase, and the movement of the new UAV through the 5GC.

- Step 5-6: When control information from the NTNMS is received, the old UxNB reduces the transmission power *OT* by θ. In addition, the new UxNB increases the transmission power *NT* by μ and moves toward the old UxNB by α
- Step 5-7: Step2 5-2 through 5-4 are repeated until all ground UEs in the service area connected to the new UxNB.

The end of the base station function of the old UxNB and the movement to the return destination are also carried out by the UTNMS, which recognizes the handover of all ground UEs.

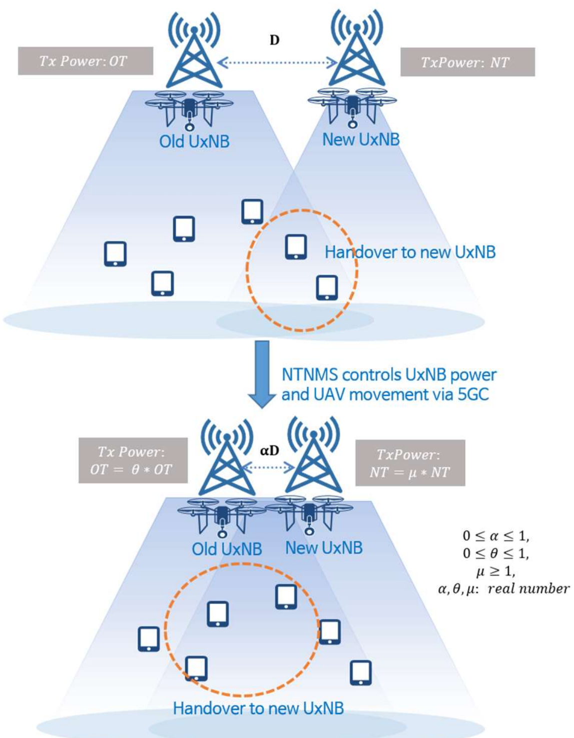

Fig. 3. Procedure of the UxNB switching

B. Functional requirements in the 5G system

Considering the operating time limit of UAVs, it is efficient that the UxNB switching is performed through the fast and safe 5G signaling path.

In the proposed UxNB switching procedure, the UTNMS, a central object in the data network, determines and performs movement control for UAVs and power control of UxNB, preventing signaling storms that may occur due to the simultaneous handover of multiple ground UEs and allowing the gradual handover to proceed.

UTMNS collects information on the location and residual power of the UAV through the 5G system from the UAV's 5G UE, and information on the transmission power of the UxNB is transmitted from the 5G core network connected to the UxNB. In addition, control of the movement and return of the UAV is delivered to the UE through the 5G system, and the transmission power control of the UxNB is also delivered to the UxNB through the 5G core network.

Given that the handover of ground mobile communication users between UxNBs must be performed through the N2 handover procedure involving the AMF, the AMF function object of 5GC can intervene in control for the UxNB switching to induce fast and safe behaviors.

In the current 5GC structure, the control signal between the NG-RAN and the 5GC is defined through the AMF and the Next Generation Application Protocol (NGAP), but no interface is defined for receiving transmission power information from the NG-RAN or for the 5GC to be involved in power control.

The proposed UxNB switching procedure requires an extension of the NGAP between the NG-RAN and the AMF to receive and control information from the UxNB and an extension of the UTNMS and 5G core internal control functions to exchange information through the UAS NF/NEF. That is, interfaces and procedures for exchanging UxNB transmission power information between the NG-RAN and the AMF and controlling the movement and transmission power of UxNB to be switched should be added to the NGAP. In addition, the procedure for transmitting information via the UAS NF and the NEF should be added to deliver information to the UTNMS that controls the UAV movement

IV. Conclusion

In this paper, we presented the UxNB-based temporary communication infrastructure consisting of the UxNB, the A2G mobile backhaul, and the UxNB-based temporary network management system to provide 5G mobile communication services. And, UxNB switching procedures and techniques for maintaining 5G cell coverage for ground UEs are presented in the infrastructure.

Currently, we are designing the standard 5GC interface to support the UxNB, and we plan to experiment by applying it to the UxNB-based temporary 5G communication infrastructure through implementation.

References

[1] 3GPP TR 22.829, “TSG Services and System Aspects; Enhancement for Unmanned Aerial Vehicles (Release 17)” , Sep. 2019.

[2] 3GPP TS 23.256, “TSG Services and System Aspects; Support of Uncrewed Aerial Systems (UAS) connectivity, identification and tracking; Stage 2 (Release 18)”, June 2023.

[3] 3GPP TS 23.501 “TSG Services and System Aspects; System architecture for the 5G System (5GS; Stage 2 (Release 18)”, June 2023.