Mobility Enhancement in 5G NR

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In Release 15 of the 3rd Generation Partnership Project (3GPP) 5G new radio (NR), the basic handover is mainly based on the long-term evolution (LTE) handover mechanism in which a network controls mobility of user equipment (UE) based on measurement reports from UE. In the basic handover, a source next generation Node B (gNB) triggers a handover by sending a handover request to a target gNB. After receiving acknowledgement from the target gNB, the source gNB initiates handover by sending to a UE a handover command containing target cell configurations. The UE synchronizes to the target cell after the radio resource control (RRC) reconfigurations are applied with the target cell configurations.

The essential requirements in NR are supporting more reliable communications with very low latency such as ultra-reliable and low-latency communication (URLLC) services. The NR system also expands its operating frequency to the much higher frequency range even above 52.6 GHz, which has very unstable channel characteristics and extremely high pathloss. A cell using the high frequency range covers smaller area than a low frequency cell. More cells are needed to cover the same area that LTE cells cover. The small cell coverage and deployments of a large number of cells compels UEs to perform more frequent handovers. To satisfy the NR requirements of reliability and latency, reducing handover failure rate and communication interruption during a handover procedure is essentially required.

The main objectives of mobility enhancements in NR Release 16 are improving handover reliability and reducing communication interruption time during a handover. The mobility enhancement features are applied to both inter-frequency and intra-frequency handover. The mobility enhancements support the high frequency range but are not limited to it. The mobility enhancement features are used for a handover procedure as well as a secondary cell group change procedure, in which a UE changes a secondary cell group while keeping its master cell group. Solutions to reduce handover interruption time and to improve handover reliability are also beneficial to high-speed trains and aerial use cases where channel environments are challenging in terms of handover performance.

The two important solutions for mobility enhancement in Release 16 are the dual active protocol stack (DAPS) based handover and the conditional handover. The DAPS-based handover allows a UE to maintain simultaneous connections with a source cell and a target cell during a handover execution time. The conditional handover enables a UE to make a final decision on a handover execution timing based on monitoring radio channels.

DAPS-Based Handover

Figure 1 illustrates the basic handover procedure in NR. Figure 1 (C) shows the successful handover scenario, and Figure 1 (D) and (E) describe the unsuccessful handover scenario. In the basic handover procedure, when the UE receives a handover command from a source gNB in Figure 1 (A), the UE immediately executes a handover to a target cell in Figure 1 (B), for example, by releasing a connection from a source cell and performing a random access to the target cell. If the random access to the target cell is successful, the UE establishes a connection to the target gNB via the target cell as shown in Figure 1 (C). On the other hand, if the UE fails to access the target cell during the handover execution, the UE loses a connection

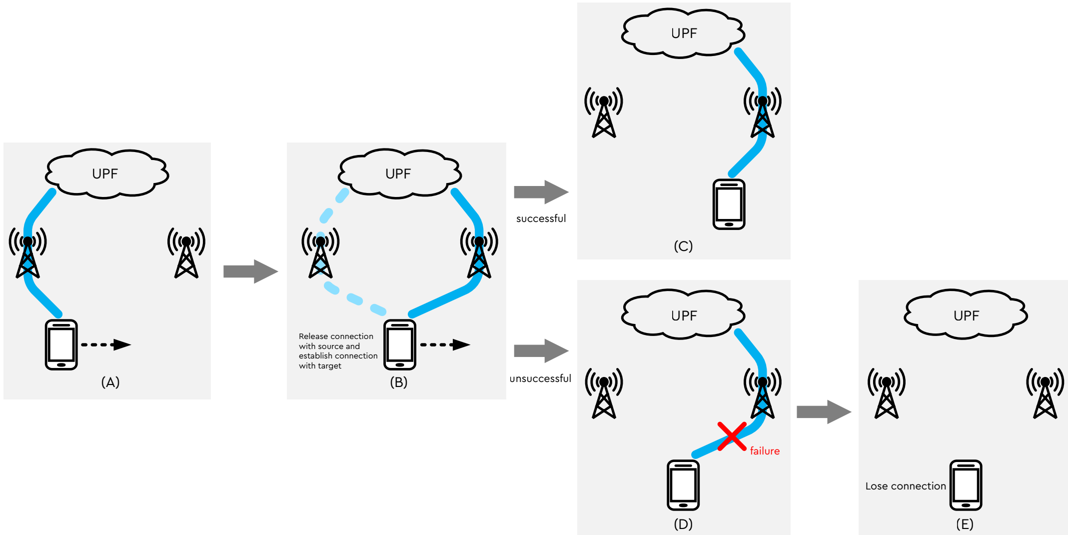

FIG. 1 Basic handover procedure

from the network, via both the source gNB and the target gNB as shown in Figure 1 (D) and (E). In NR network using high frequency range and beamforming, the probability of handover execution failures is much higher than LTE, as it dramatically increases connection loss rates during handover procedures.

Moreover, in the basic handover procedure, packet communication between a UE and a network is interrupted during a time between releasing a connection with a source gNB and completing an access to a target gNB. The interruption of packet communication during the handover may be a critical problem for URLLC services.

To resolve the unreliable handover issues, the DAPS-based handover allows a UE to keep simultaneous bearer connections with both a source gNB and a target gNB during a handover procedure. Figure 2 shows the overall DAPS-based handover procedure. Figure 2 (C) describes a successful DAPS-based handover scenario and Figure 2 (D) and (E) are an example failure scenario of the DAPS-based handover. In Figure 2 (A), a UE receives a handover command, from a source gNB, indicating one or more data radio bearers (DRBs) are configured as a DAPS bearer. A network maintains radio protocols for the DAPS bearers in both the source gNB and the target gNB during a DAPS handover to use resources of both the source gNB and the target gNB. In response to receiving the handover command, the UE suspends signal radio bearers (SRBs) for control plane communications with the source gNB and accesses a target cell. During the access procedure to the target cell, the UE keeps receiving packets of the DAPS bearers from the source gNB as shown in Figure 2 (B). After the successful access to the target cell, the UE receives a source release indication from the target gNB and releases the connection with the source cell in Figure 2 (C). If the UE fails to access the target cell during the handover execution as Figure 2 (D), the UE reverts to the source cell configuration and resumes the suspended SRBs for the source gNB as shown in Figure 2 (E). The DAPS-based handover enables a UE to maintain a network connection without interruption of communication when an attempt to access a handover target cell is unsuccessful.

Conditional Handover

Another approach to increase reliability of the handover procedure in NR is letting a UE decide a timing of executing its handover. In the basic handover procedure of NR in Figure 3, a source gNB determines to handover a UE to a target cell based on measurement reports from the UE and requests for the handover of the UE to a target gNB. After receiving an acknowledgement for the handover request, the source gNB sends a handover command to the UE. Once receiving the handover command,

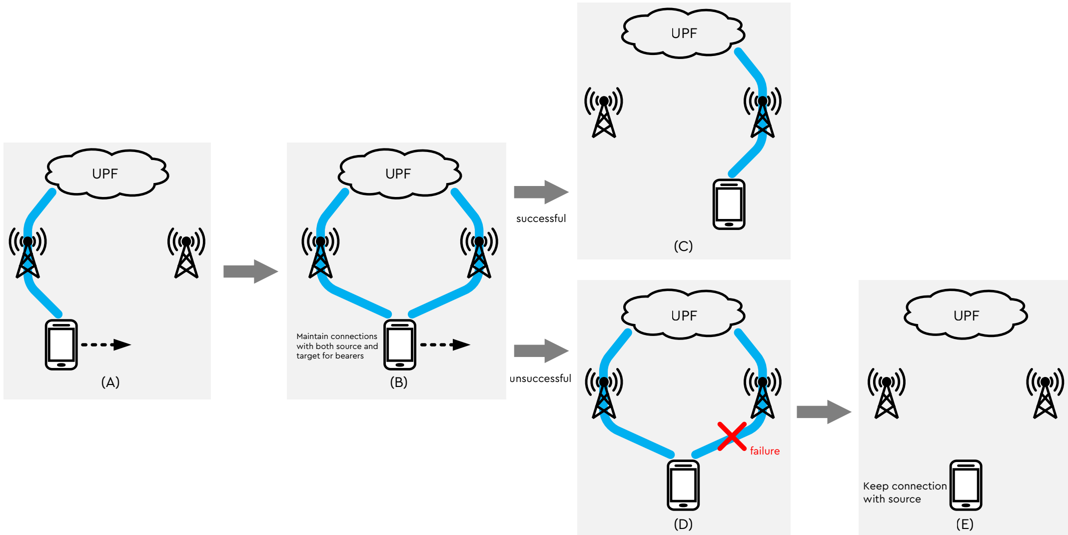

FIG. 2 DAPS-based handover procedure

the UE executes the handover to the target cell. In high frequency range of the NR system, a channel quality changes very fast. During the time period from the channel measurement of UE for the measurement reports and reception of the handover command, the channel quality of the target cell may worsen. It may cause a failure of accessing to the target cell and the UE eventually fails in the handover.

To reduce the time gap between the channel measurement and the handover execution, in the conditional handover procedure, a UE determines a handover execution timing based on its latest channel measurement results. In Figure 4 (A), a UE receives a handover command containing an execution condition for a handover to a target cell. However, while the execution condition is not met for the target cell, the UE uses the source cell without accessing to the target cell in Figure 4 (B). The UE keeps monitoring the channel of the target cell and checks whether the execution condition for the handover is met. Based on the continuous measurement of the target cell, the UE determines that the handover execution condition is met for the target cell and finally initiates to access the target cell in Figure 4 (C). The UE successfully completes the handover procedure in Figure 4 (D).

For example, an execution condition for a handover may be a threshold value of a received power from a target cell. While a received power from the target cell is lower than the threshold value, the UE

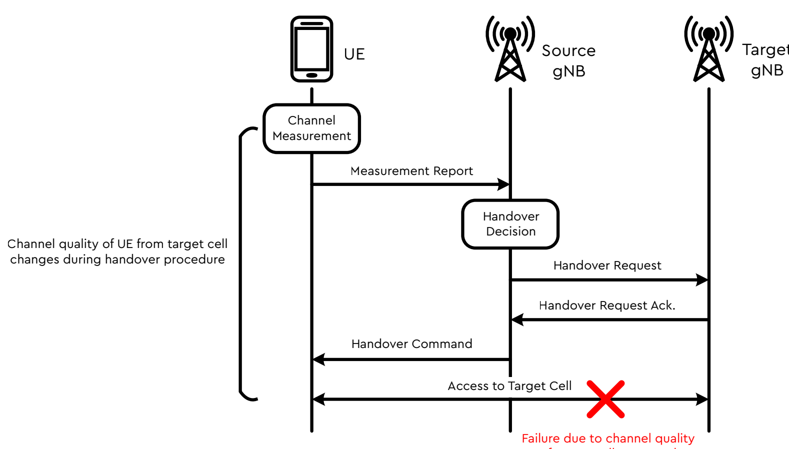

FIG. 3 Channel state change during handover procedure and handover failure

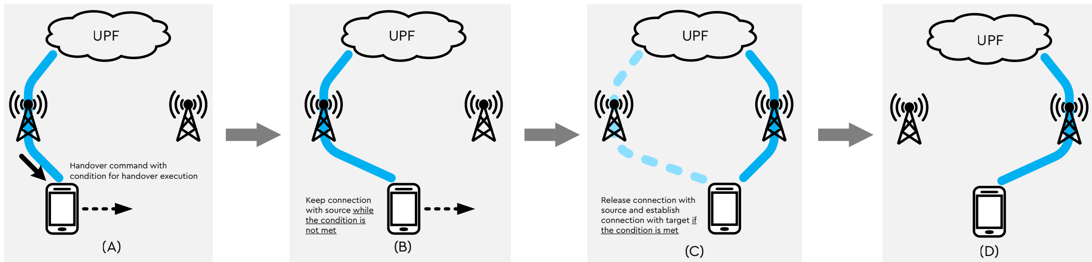

FIG. 4 Conditional handover procedure

keeps the connection with a source cell and does not attempt to access the target cell. Once the received power from the target cell becomes equal to or larger than the threshold value, the UE releases the connection with the source cell and initiates to access the target cell.

Furthermore, the unreliable channel state in high frequency range may cause the unexpected connection loss from the source cell. During the basic handover procedure, if a UE detects a connection failure from a source cell, the UE performs a connection reestablishment procedure. During the connection reestablishment procedure, the UE may release configurations for communication with a network and need to receive new configurations for communications. It causes signaling overheads and delay of the communications. In the conditional handover procedure, after receiving a handover command with an execution condition, a UE may also detect a connection failure from a source cell before the execution condition is met for the target cell. However, instead of performing the connection reestablishment procedure, the UE can access a target cell based on the configuration parameters received via a handover command regardless of the execution condition being met if the UE selects the handover target cell as an accessing cell after the connection failure with the source cell. Using the configuration parameters configured for handover to a target cell, when a connection failure from a source cell happens, reduces signaling overheads and communication delay.

Abbreviations

3GPP	3rd Generation Partnership Project
DAPS	Dual Active Protocol Stack
DRB	Data Radio Bearer
gNB	Next Generation Node B
LTE	Long-Term Evolution
NR	New Radio
RRC	Radio Resource Control
SRB	Signaling Radio Bearer
UE	User Equipment
URLLC	Ultra-Reliable and Low-Latency Communication

References

[1] 3GPP TS 38.300 V16.5.0 (Release 16) Technical Specification Group Radio Access Network; NR; NR and NG-RAN Overall Description; Stage 2

[2] 3GPP TS 38.331 V16.4.1 (Release 16) Technical Specification Group Radio Access Network; NR; Radio Resource Control (RRC); Protocol specification

[3] 3GPP TS 38.423 V16.5.0 (Release 16) Technical Specification Group Radio Access Network; NG Radio Access Network (NG-RAN); Xn application protocol (XnAP)

About the Author:

Kyungmin focuses on research and development of radio access network procedures for 5G and LTE. Prior to joining Ofinno, he held a senior research position at LG Electronics and participated in 3GPP standardization activities. Kyungmin is an inventor in over four hundred granted or pending US patent applications. He received his Ph.D. in Electrical and Electronic Engineering from Yonsei University, Seoul, South Korea in 2011.

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