Multi Carrier Cell management and mobility enhancement

Jun-Sik Kim, Soon-Gi Park and Yong-Seouk Choi
Mobile Communication Research Division
Electronics and Telecommunications Research Institute
Daejeon, Republic of Korea
Email: {junsik, yoyo, choiys}@etri.re.kr

***Abstract*—As the demand for high-capacity services with very high frequency increases, various technologies for increasing communication capacity have been proposed. Carrier aggregation and dual connectivity technology based on multi-carrier are typical examples. In this paper, a technique for reducing delay through cell operation based on multi-carrier is discussed.**

Keywords—mobility, multi carrier, carrier aggregation, dual connectivity

I. Introduction

The ultra-high frequency band has a large bandwidth and is easy to allocate continuous radio resources, thereby increasing the capacity of the communication system. It has only been applied in limited fields such as indoor data centers and wireless backhaul. However, as beamforming technology based on multiple antennas is applied to mobile communication systems, research to utilize ultra-high frequency bands including terahertz bands for mobile communication has proceeded. Ultra-high frequency mobile communication wireless access utilizes ultra-fine beamforming technology based on a large-scale antenna array and distributed multi-point multi-antenna technology to increase system capacity and improve performance. It is expected that this will change with wireless access. The main content of this paper is a control transmission procedure and data transmission procedure for radio resource allocation by operating UE-centric carrier aggregation(CA) through simplified information transmission and dynamic operation for CA when a cell is configured based on multi-beam TRP.

II. Problem Statement

Through research on problems for utilizing high-frequency bands, the main issues that should be specially considered because of its inherent directivity and propagation loss features in terms of designing mobile communication networks for high-frequency channel characteristics are as follows[1].

- Blockage: high penetration loss due to obstacles. It is a problem that cannot be solved simply by increasing the transmit power, and it occurs according to the dynamic topology change due to obstacles in the communication environment[2].
- Deafness: a situation in which the main beams of the transmitter and receiver are not aligned. It is a problem that intensifies according to the high-speed movement of users and interferes with communication link connection.
- Mobility: QoS degradation, such as communication blockage, often occurs due to frequent beam switching or handover according to the movement of a UE or a change in link status due to a narrow communication area based on beams.

To overcome blockage, a wireless high frequency communication system must search for and identify an unblocked alternative directional space channel. However, since this search involves a significant amount of new beamforming overhead, a new type of waiting time is introduced (beamforming waiting time). As a result, designs for cellular networks must find a way to establish bypass communication through NLoS(Non Line of Sight) components.

Deafness is maximized at the cell edge, so if the cell configuration is based on a legacy concept, it has a negative effect on the complexity of link configuration and increases synchronization overhead. Therefore, the existing design for the initial access procedure must be reconsidered, and as a result, a new cell concept, not a traditional cell concept, must be redefined[3][4].

Mobility includes a beam level mobility management technology for managing movement between beams within one communication area and a cell level mobility management technology for managing movement between cells. The beam-level mobility management technology maintains a stable link state by allocating optimal beams within a UE(User Equipment) to BS(Base Station)s. Beam level mobility management technology consists of beam selection that selects an optimal beam, beam switching that changes to an optimal beam that is better than the currently assigned beam, and beam failure recovery technology that quickly recovers from beam alignment errors. The cell-level mobility management technology maintains a stable connection with a UE by allocating an optimal cell among cells around the BS to the BS. Cell-level mobility management technology consists of cell selection that selects an optimal cell, handover that changes to an optimal cell that is better than the currently allocated cell, and RLF recovery technology that quickly recovers from an error in the connection state with the UE[5].

III. Multi Carrier

A. Primary and secondary component carrier

A CA component carriers may consist of one primary component carrier (PCC) and multiple secondary component carrier(SCC)s. SCC performs the function of transmitting and receiving data without control information. [6].

B. CA and DC

UE accesses one BS, configures a PCell through a PCC through a CA procedure according to a base station policy, receives radio resources allocated in the SCell area through the configured SCC as necessary, and communicates.

The CA decision is driven according to the amount of data available in the buffer in both uplink (UL) and downlink (DL). A BS or node is responsible for appropriate resource allocation for both uplink and downlink. In order to provide appropriate resources in the uplink, the BS needs information from the BS related to the amount of data generated by the application. The UE must report the buffer status of a certain radio bearer (RB) indicating the required amount of uplink resources to the base station. Resource allocation is performed based on the QoS characteristics of the radio bearer and the reported buffer status. The mapping of radio bearers to logical channel groups is based on the QoS attributes of the radio bearer, such as QoS Class Identifier (QCI). The BS reports the aggregate buffer status for radio bearer combinations of logical channel groups. The UE transmits a buffer status report (BSR) to the BS based on conditions such as when new data arrives or high priority data arrives in a previously empty buffer indicating the start of UL data transmission. A timer is maintained to keep the BS updated on the current state of the buffer and the amount of data still to be transmitted (periodicBSR-Timer), and when this timer expires the BSR is triggered. The BS operates a scheduler through information transmitted from the UE and collected in the BS, and configures a CC accordingly to perform radio resource allocation. The figure shows an example of PCC/SCC operation. The SCC configured by the PCC is driven by the command of the MAC layer, and may be inactive by the preset RRC deactivation timer or inactive by the MAC CE command. An inactive SCC can be activated by a command from the MAC layer[6].

As shown in the Fig. 1, a master cell group (MCG) is a group of cells served by a master node (MN), which constitutes CA and DC with a primary cell (PCell) and a secondary cell (SCell)1 or/and SCell2. A Secondary Cell Group (SCG) is a group of cells served by a Secondary Node (SN) that uses a PSCell and SCell1 or/and SCell2 to form a CA and DC. [6].

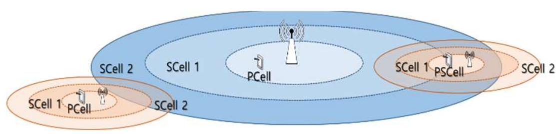

Fig. 1. CA and DC deployment

C. PCell / SCell Management

In a Base Station (BS) implementing Carrier Aggregation (CA) and Dual Connectivity (DC) technologies, the operating state of a Secondary Cell (SCell) during events like PCell (Primary Cell) changes, including handovers, is detailed below:

- SCell Initialization: An SCell, established via Radio Resource Control (RRC) messages, remains in an initial inactive state until it receives a MAC Control Element (MAC-CE) signal.
- SCell Activation: In the active state, the SCell facilitates the transmission and reception of Rx CSI (Channel State Information) and Tx CSI-RS (Channel State Information Reference Signal). Additionally, PUCCH (Physical Uplink Control Channel) configuration aligns with PDCCH (Physical Downlink Control Channel) conditions.
- SCell Candidate State: Before deactivation by either a MAC-CE or RRC-configured deactivation timer, the configured SCell remains in a candidate state. During this period, Rx CSI/Tx CSI-RS signals, except those related to control channels, are maintained.
- SCell Candidate Management: SCells in the candidate state are managed as candidates for a PCell change. The transition to PCell occurs when selected by the UE.

PCell changes can occur in different scenarios:

- PCell change without altering the SCell.
- PCell and SCell change together.
- Conversion of an SCell into a PCell.

Changing the current PCell typically involves a handover procedure, which can introduce unnecessary delays when switching to a target SCell that utilizes the same BS resources. To minimize such delays, switchable SCell groups are managed through Conditional Handover (CHO) and L1L2 triggered mobility (LTM) procedures, already established in the standard. These procedures enable the selection of candidate prepared SCell groups for PCell switching, reducing the PCell change time and minimizing delays.

To facilitate this process, SCell groups are prepared using scheduler information, scheduling control information, mobility control information, and more. SCells in a candidate state are managed as potential PCells and transitioned into PCells based on UE selection. During this transition, the BS prepares for a PCell reconfiguration procedure through RRC messages within the control plane and executes PCell switching at the UE's request.

When the PCell is changed via a handover procedure between different BSs, the handover message includes information about the SCell currently providing the service. If service overlaps between SCells from different BSs occur, a separate signal is provided

D. Message Flow

Fig. 2 illustrates a flow chart of an intra-DU cell operation message based on CA. While performing data communication with the BS DU in the RRC_Connected state, the BS periodically reports neighboring cell information measured by the UE to the BS, and the BS CU controls it. When the BS CU determines the selection mode configuration so that the BS can select the currently configured neighboring cell, which information is transmitted through the RRCReconfiguration message through the BS DU, and preparation for DU selection is completed through RRCReconfigurationComplete of the BS.

The UE performs a synchronization procedure through L2 measurement of signals (SSB and CSI-RS). After that, the PCell change procedure is performed through the L1 measurement report. Based on the scheduler information, scheduling control information, and mobility control information in the SCell group information received from the previous PCell, the UE selects a desired cell and transmits the information to the CU. After carrying out the transition of PCell to other cell, the UE completes the cell change procedure through data and PDCCH reception.

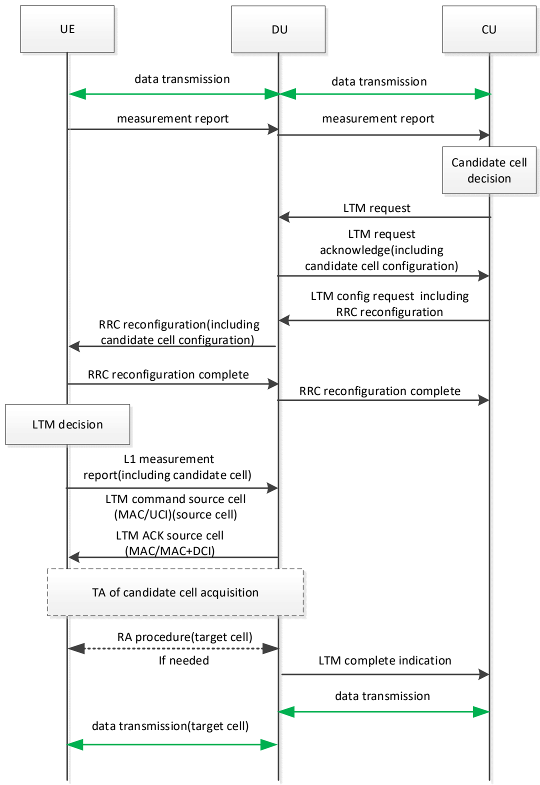

Fig. 2. CA based UE-cetric cell operation message flow chart

IV. CONCLUSION

Ensuring continuous service in the context of discontinuous SCells based on FR2/THz SCCs with ultra-high-frequency characteristics poses significant challenges. The conventional cell operation method, reliant on control layer commands, introduces substantial delays. In this paper, we propose a UE-centric cell configuration approach to address frequent component carrier reconfiguration and handovers within a narrow and discontinuous cell area when used as a secondary cell. Our solution involves dynamically forming component carrier groups based on the UE's situation, complemented by LTM techniques.

To enhance service continuity while minimizing latency, we prepare a set of candidate cells that can be seamlessly transitioned to, given the current situation, sharing the same BS or scheduler as the PCell. The management of this switchable SCell group is facilitated through the LTM procedure. Subsequently, the PCell selection process leverages the candidate SCell group. This UE-centric cell management method is designed to maximize service continuity for low-latency, high-capacity services.

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REFERENCES

[1] H. Elayan, O. Amin, R. M. Shubair, and M. S. Alouini, “Terahertz communication: The opportunities of wireless technology beyond 5G,” in International Conference on Advanced Communication Technologies and Networking (CommNet), April 2018, pp. 1–5.

[2] TERRANOVA, https://ict-terranova.eu/, accessed: 01-04-2019.

[3] T. Kurner and S. Priebe, “Towards Terahertz communications status in research, standardization and regulation,” Journal of Infrared, Millimeter, and Terahertz Waves, vol. 35, no. 1, January 2014, pp. 53–6.

[4] C. Han et al., “On medium access control schemes for wireless networks in the millimeter-wave and Terahertz bands,” Nano Commun. Netw., vol. 19, March 2019, pp. 67–80.

[5] Junsik Kim, SoonGi Park, “Ad hoc cluster management for converage extension on high frequency mobile backhaul”, 2021 International Conference on Information and Communication Technology Conference(ICTC), 2020

[6] Junsik Kim, SoonGi Park, “Issues of Dual Connectivity and Carrier Aggregation enhancement for low latency EMBB”, 2021 International Conference on Information and Communication Technology Conference(ICTC), 2021