Load Balancing Beam Selection Algorithm using Location-based Fingerprints according to RSRQ

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***Abstract*—Unmanned Aerial Vehicle (UAV) is attracting attention as a key element of the New Radio (NR) system as it can exceed the limits of the ground network to prepare for the rapidly increasing data usage and create new application services. However, high-altitude UAVs have a high Line-Of-Sight (LOS) probability, resulting in interference problems between adjacent cells in multi-cell networks. Therefore, this paper proposes an algorithm that selects the optimal beam to reduce the impact of interference and ensure high transmission efficiency. Specifically, the proposed algorithm consists of the process of building a Fingerprint Database (fingerprint database) and the process of selecting a load balancing beam. Simulations were conducted based on the downlink system for performance analysis, and signal-to-interference-plus-noise cumulative distribution function (SINR CDF) and spectral efficiency cumulative distribution function (SE CDF) are used as performance analysis indicators. As a result of performance analysis, it was confirmed that the proposed algorithm efficiently uses the necessary resources, reduces the impact of interference, and increases the performance of the desired signal.**

Keywords*—beam selection with load balancing, cumulative distribution function, fingerprint database, signal-to-interference-plus-noise ratio, spectral efficiency, unmanned aerial vehicle.

I. INTRODUCTION

With the recent increase in data demand, various technologies are being developed to support it. Among them, UAVs with high speed and high altitude characteristics are attracting attention, but high-altitude UAVs are more likely to be affected by inter-cell interference from other BSs or UEs as the probability of Line-Of-Sight (LOS) increases, and this effect causes more performance degradation as the number of UEs serviced at the same time in the same area increases [1]. To reduce this impact, research on direct beamforming technology is being conducted, and beam selection algorithms in various ways of selecting the optimal beam to maximize transmission efficiency are being studied [2], [3]. This paper proposes an algorithm to select the optimal beam through load balancing presented in this paper using the fingerprint database according to the user's location to ensure high transmission efficiency in the UAV-supported Massive system.

II. SYSTEM MODEL AND CHANNEL MODEL

In this paper, a 3GPP-based UAV channel model is applied, and a spatial channel model (SCM) is applied between T-BS and UE. SCM uses a statistical model using parameters statistically calculated through repeated measurements and a deterministic model using a ray-tracing model that mathematically expresses and tracks propagation characteristics. Among them, this paper utilizes a geometry-based statistical model that uses a mixture of these two models. In order to set the channel parameters according to the situation when utilizing the SCM model, this paper considers the UMa-AV scenario.

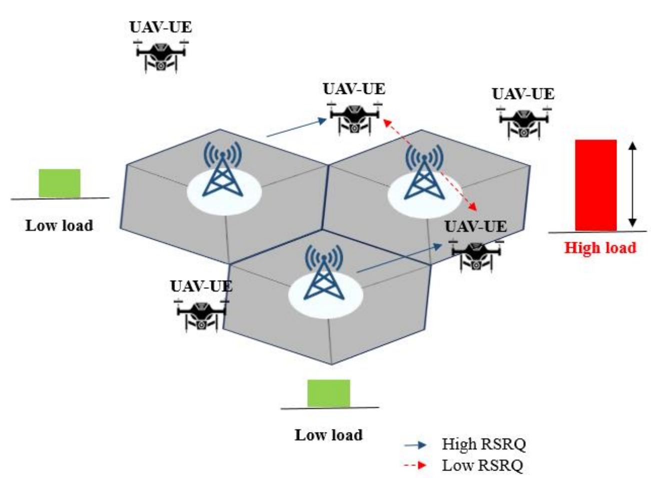

Fig. 1. Cellular downlink systems.

III. Position Fingerprint Database construction

In this paper, Reference Signal Received Quality (RSRQ) was used as a location-based fingerprint database measurement index. Reference Signal Received Power (RSRP) considers only signals from serving cells received by the terminal, but RSRQ also considers signals received from target cells other than serving cells, so load-balancing can also benefit.

$$\mathrm{RSRQ} = N \times \mathrm{RSRP}/\mathrm{NR} - \mathrm{carrier\ RSSI} \qquad (1)$$

The location-based fingerprint database is built using RSRQ as a metric for all UAV-UE located in each cell. When building a database, information on UE location, serving cell ID, and optimal beam ID is stored, and information on beams is also stored in target cells for load balancing in the case of UEs that are susceptible to interference between adjacent cells.

IV. Load Balancing Beam Selection Algorithm

$$P_o^* = \underset{a \in 1,\dots,A+n}{\operatorname{argmin}} |P_o - P_a|^2 \qquad (2)$$

In the case of UEs, location information can be easily utilized due to the built-in high level of Global Positioning System (GPS). In addition, the T-BS matches the location information of the received UAV-UE against the location information measured in the fingerprint database. The matching process is performed at the point where the error between the actual location of the UE and the location measured in the fingerprint database is minimized, as shown in Equation 2. When the matching process is completed, a fingerprint database corresponding to the location is determined, and the serving cell ID and the optimal beam ID stored in the database can be utilized. Moreover, in the case of a UE that is susceptible to interference, beam information on a target cell may be used. Fig. 1 describes how RSRQ metrics capture the effects of network loads and can be used for load balancing purposes. When the UAV-UE steer the beam toward a further but less loaded cell, even if the distance to the cell is greater, the amount of observed interference is reduced, resulting in a higher RSRQ, resulting in a connection to the less loaded cell. Therefore, in this paper, load balancing is performed when the RSRQ value for the serving cell differs from the RSRQ value in the target cell by more than the threshold value using the previously established fingerprint database.

V. Simulation Results Analysis

Fig. 2 is the simulation result of the load balancing effect according to the measurement index. In other words, it is a simulation result when load balancing is performed based on RSRP and RSRQ as a measurement index, and the number of UAV-UE per sector for high-load cells is set to 20, and the number of UAV-UE for each sector is set to 1. Performance analysis uses SINR CDF and SE CDF. As shown in Fig. 2, the performance differs by about 1.0 dB when load balancing is applied based on RSRQ compared to when load balancing is applied based on RSRP based on CDF 0.5. This is because, as described in the previous section, the signal in the target cell as well as the serving cell, that is, the RSRQ, considers all interference signals.

As confirmed in the previous simulation, it is verified that the overall performance is improved because of load balancing, as shown in Fig. 3, when SE CDF applies the RSRQ-based load balancing algorithm.

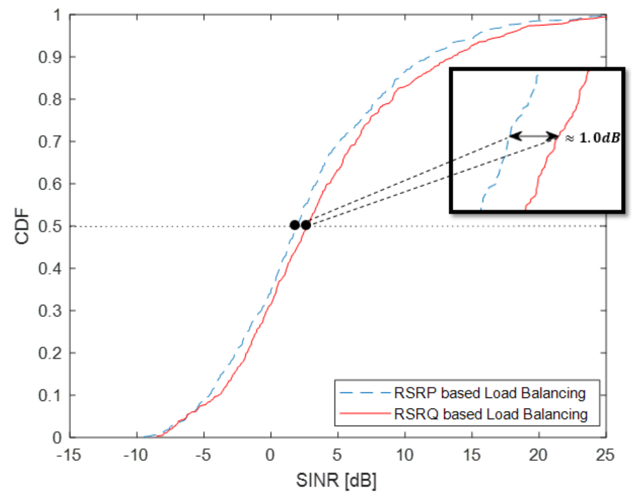

Fig. 2. SINR CDF of load balancing effect according to measurement metrics.

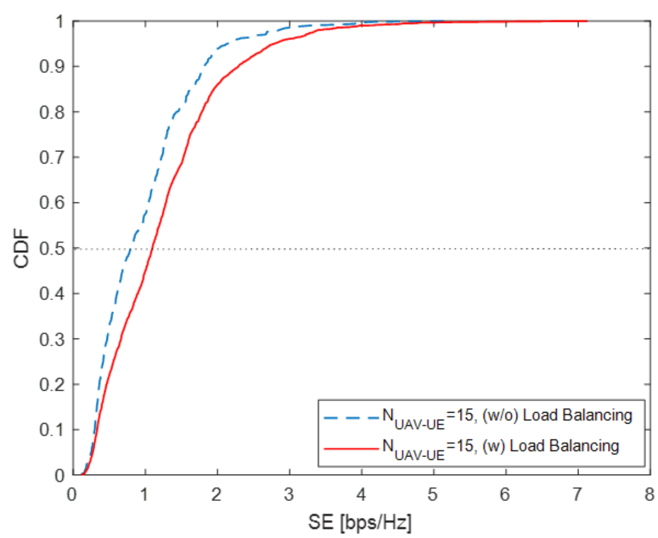

Fig. 3. SE CDF according to load balancing beam selection algorithm.

VI. Conclusion

In this paper, a load balancing beam selection algorithm method using a location-based fingerprint database was proposed. In fact, as a result of analyzing the performance of the algorithm proposed in this paper using system-level simulation, it was possible to select the optimal beam with high efficiency through the load balancing beam selection algorithm.

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