# Utilizing Carrier Aggregation for Even Beam Distribution in 3D Beamforming

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*Abstract—* **3D beamforming is a highly attractive issue in 5G telecommunication. Equipped with 2D antenna arrays, it allows vertical sectorization within a cell as well as horizontal one, by making a beamforming zone for the corresponding sector. However, there is considerable inequality among the areas of beamforming zone. The farther from the base station, the bigger the beamforming zone area is. In this paper, we propose to utilize carrier aggregation (CA) for relieving the uneven beamforming zone area problem and prove this method is more efficient in improving cell throughput especially in mmWave environment.**

***Keywords*—3D Beamforming, Carrier Aggregation, 5G Telecommunication**

## I. INTRODUCTION

3D beamforming allows both horizontal and vertical beam pattern adaption in order to enhance system performance over the conventional beamforming techniques [1][2]. Lots of recent researches in 5G communication also consider adopting 3D beamforming for mmWave systems [4][5].

In 3D beamforming, each beam is formed and controlled by antenna arrays. Then each cell can be split into multitude of beamforming zone as shown in Figure 1.

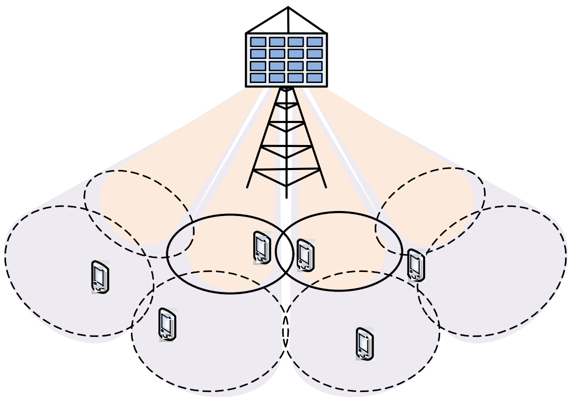


**Figure 1.** Multiple beamforming zones using 3D beamforming.

One of the problems of 3D beamforming is its inequality of each beamforming zone area [3][4]. The farther from the base station, the bigger the beamforming zone area is. Even though the considered cell sizes are small due to the propagation limitation of mmWave, most part of the cell area was covered by only a small portion of 3D beamformings [4].

This inequality of beamforming zone area causes inequality of users each beamforming supports, i.e. uneven average radio resource occupation of each user equipment (UE).

Prior researches considered relay systems to be adopted in this situation. Relays are helpful in filling coverage holes but they also can interfere neighbour beamforming zone area [4]. In this paper, we will show this inequality of radio resource occupation can be alleviated by installing other BSs for carrier aggregation (CA) [6] at adequate places.

## II. THE INEQUALITY OF 3D BEAMFORMING ZONE

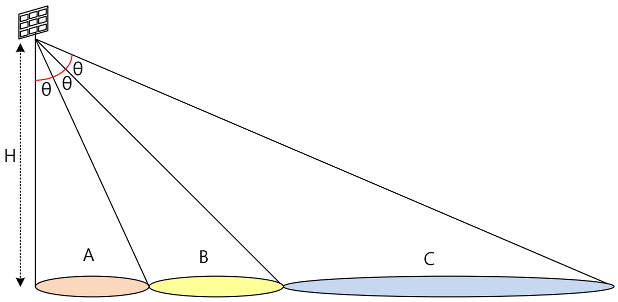
The area of beamforming zone can be varied due to the height and down tilt angle of base station (BS) antenna. If the BS antenna configuration is as shown in Table 1, the expected beamforming zone of that cell in flat terrain is as depicted in Figure 2 and Table 2.

**TABLE 1.** BS CONFIGURATION PARAMETERS.

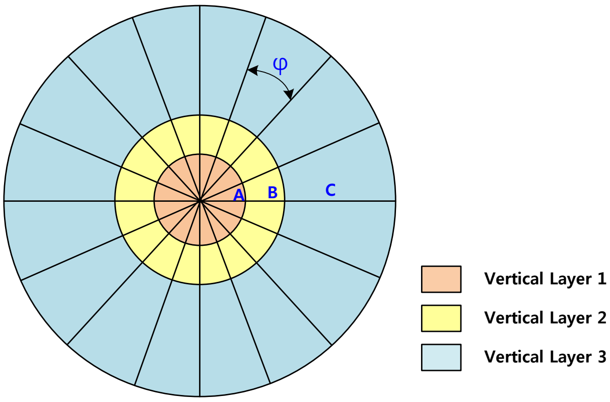
| BS Parameter | | value |
|---|---|---|
| BS antenna height (H) | | 50 m |
| Vertical beamforming angle (θ) | | π/8 |
| Horizontal beamforming angle (φ) | | π/8 |
| Number of vertical layers | | 3 |
| Cell radius | 1st Vertical Layer | 10.36 m |
| | 2nd Vertical Layer | 25 m |
| | 3rd Vertical Layer | 60 m |

Figure 2 clearly shows that the relation between the distances from BS and the area of beamforming zone. The calculated area of each beamforming zone A, B and C under the parameter of Table 1 also certifies it as is shown in Table 2.

In real cell deployment, each cell radius is much greater, every beamforming angle is varied or steerable, and each beamforming zone shapes oval and surrounded by interference zone [4]. However we apply simpler model of beamforming zone as shown in Figure 2 for convenient verification of proposed method.




(a) Vertical view of beamforming layers




(b) Horizontal view of beamforming layers

**Figure 2.** The deviation of beamforming zone area with the distance.

While the transmission data rate of each beamforming does not vary widely, its coverage is quite different according to the vertical layer it belongs to. Table 2 shows the beamforming zone of belonged to 3rd vertical layer is as wide as 28-fold of that belonged to 1st vertical layer.

**TABLE 2.** BEAMFORMING ZONE AREAS OF DIFFERENT VERTICAL LAYERS.

| Vertical Layer | 1st Layer (A) | 2nd Layer (B) | 3rd Layer (C) |
|---|---|---|---|
| **Single beamforming zone area ($m^2$)** | 84.22 | 406.65 | 2370.15 |
| **Total beamforming zone area (%)** | 2.94 | 14.21 | 82.84 |

These unequal areas between beamforming zones cause uneven service quality per equal area in the same cell. If users are evenly distributed in that cell, 82.84 percent of users are supported by beamformings of 3rd vertical layer while only 2.94% of users receive service of 1st vertical layer beamforming. Figure 3 shows the uniformly distributed 1,000 user's occupation of radio resources under this circumstance. All users in each beamforming are supposed to share the equal portions of radio resources.

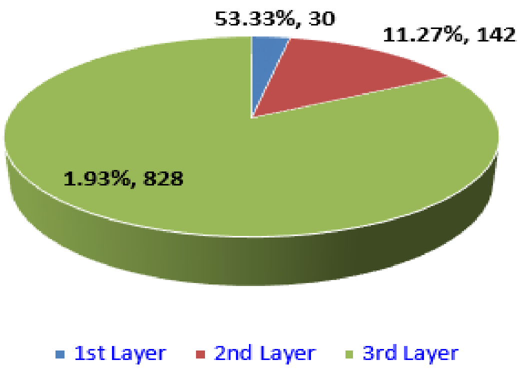



**Figure 3.** Occupied Radio Resource per UE (%), Number of UEs.

Figure 3 depicts among 1000 thousand of uniformly distributed UEs, only 30 UEs are supported by 1st vertical layer and they can occupy about 53.33% radio resource of each beamforming, while most UEs – 828 UEs- are belonged to 3rd vertical layer and shares only 1.93% radio resources of each beamforming.

In this system, even if the serving BS offers CA with 2 more frequency band, the benefit of CA converges to only 17.16 percent of UEs in the cell and overall resource occupation of UE does not varied.

## III. USING CA FOR RELIEVING BEAMFORMING ZONE DEVIATION

Many remedies can alleviate this inequality. They are the sharper beamforming, heterogeneous networking (HetNet) [7], relaying [4][5], etc. CA can be one of those solutions also.

Generally, CA is used to improve data rates for UEs and many scenarios are proposed of its deployment [6]. If CA is offered by same BS, the benefit is concentrated only a few UEs which are adjacently placed to BS in 3D beamforming system. However, if extra CA base station (CA-BS) is located adequately apart, it can reduce the inequality of user service quality.

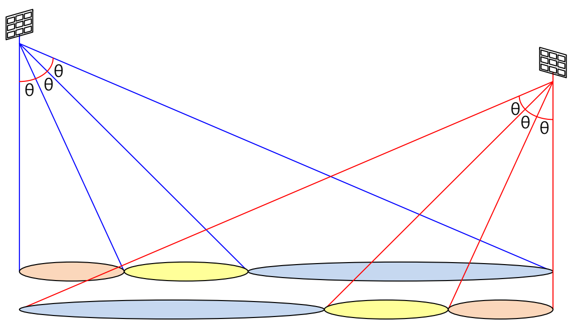



**Figure 4.** The effect of CA for relieving beamforming zone area deviation.

Figure 4 shows that adequately located another BS can offer effectively dense beamforming to much of thin beamforming zone area by means of CA. Figure 5 depicts 2-

dimensional view of an exemplary CA-applied cell. Each CA-BS is supposed to be the same type with the main BS. This figure shows much part of cell edge region can be supported by CA -BS.

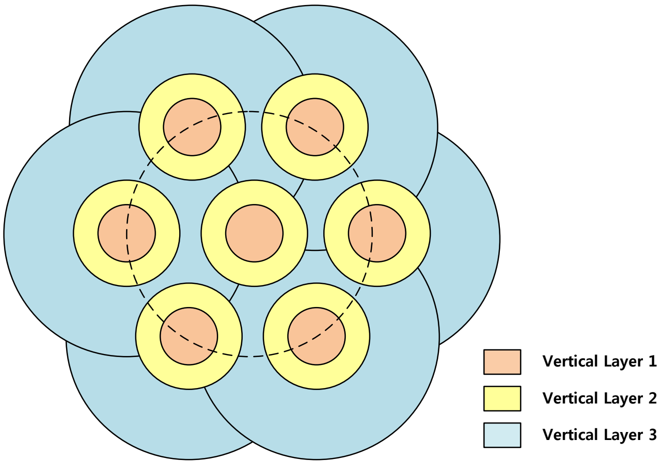



**Figure 5.** Beamforming layer of CA-applied cell.

Figure 5 depicts the situation of 3 different CA frequency bands are used. Each CA-BS is supporting 2 more adjacent neighbor cells also and its 3rd vertical layer beams can be adjustable to avoid inflicting interference to particular UEs.

With the cooperation of CA-BS, more than half of the UEs of our exemplary system can be supported by either 1st or 2nd vertical layer signal as shown in Table 3.

**TABLE 3.** BEAMFORMING ZONE AREAS UNDER CA CIRCUMSTANCE.

| CA Type | 1st Layer + 3rd Layer | 2nd Layer + 3rd Layer | 3rd Layer + 3rd Layer |
|---|---|---|---|
| **Total beamforming zone area (%)** | 8.82 | 42.63 | 48.55 |

Figure 6 depicts the calculated number of UEs and their radio resource occupation in each beamforming. Among uniformly distributed 1,000 UEs, now 486 UEs are supported by solely 3rd vertical layer, and they can occupy 9.88% of beamforming's radio resource. Although the exact radio resource occupation percentage can be varied with different resource assignment strategy or CA-BS parameters, this picture shows that each UE can at least about 10 % of radio resource of each beamforming, and better degree of freedom in resource assignment is offered.

This displacement of extra CA-BSs is more desirable in mmWave system. Since the propagation limitation of mmWave is sterner compared to other commercial band signal [8], its cell size is relatively small and the extra CA-BSs' signal can easily cover the wide range of each cell, while any possibility can be evaded by beam steering.

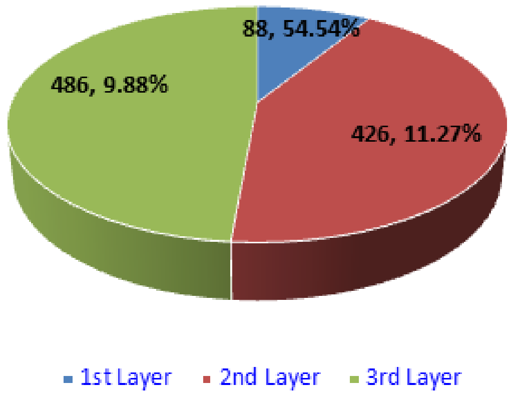



**Figure 6.** Occupied Radio Resource per UE (%), Number of UEs with CA.

Generally CA signals are transmitted from the same serving BS to enhance user data rate. However in the aspect of beamforming zone area inequality in 3D beamforming, we can see that offering CA by separated BS is desirable.

The separated CA-BSs are also important in case of rainfall attenuation, since mmWave is especially vulnerable to the effect of rainfall, separated CA-BSs can fill the coverage gap between the diameter-reduced cells in the rainy condition.

## IV. CONCLUSIONS

In this paper, we showed the inequality of 3D beamforming zone area can be effectively alleviated by the support of appropriately placed extra CA base stations. Various terrain, UE distribution, and service environment influence the most efficient cell disposition, and our research shows cooperation with remote CA base station is also vital in user service quality in 3D beamforming environment.

## ACKNOWLEDGMENT

This research was supported by 'The Cross-Ministry Giga KOREA Project' of The Ministry of Science, ICT and Future Planning, Korea. [GK14N0100, 5G mobile communication system development based on mmWave]

## REFERENCES

[1] J. Koppenborg, H. Halbauer, S. Saur, C. Hoek, "3D beamforming trials with an active antenna array," Smart Antennas (WSA), 2012 International ITG Workshop on, 7-8 March 2012, pp. 110-114

[2] B. Ku, D. Ahn, S. Lee, A. Shishlov, A. Reutov, S. Ganin, A. Shubov, "Radiation Pattern of Multibeam Array Antenna with Digital Beamforming for Stratospheric Communication System: Statistical Simulation," ETRI Journal, vol. 24, no. 3, Jun. 2002, pp. 197-204.

[3] J. Jung, "Method and apparatus for jointly transmitting/receiving a signal in a mobile communication system," K.R. Patent 10-2013-0127192, Nov. 22, 2013.

[4] JungSook Bae, Yong Seouk Choi, Jun Suk Kim, Min Young Chung, "Architecture and Performance Evaluation of MmWave Based 5G Mobile Communication System," ICTC 2014, 22-24. Oct. 2014, pp.847-851

[5] JungSook Bae, Hyun-Seo Park, SookJin Lee, Yong Seouk Choi, Jun Suk Kim, Min Young Chung, "System Coverage of MmWave Based 5G Mobile Communication System," APCC 2014, October 1-3, 2014, pp.1-4

[6] Shen, Z., Papasakellariou, A., Montojo, J., Gerstenberger, D., & Xu, F. (2012). Overview of 3GPP LTE-advanced carrier aggregation for 4G wireless communications. Communications Magazine, IEEE, 50(2), 122-130.

[7] J. Wang, J. Liu, D. Wang, J. Pang, G. Shen, "Optimized Fairness Cell Selection for 3GPP LTE-A Macro-Pico HetNets," Vehicular Technology Conference (VTC Fall), 5-8 Sept. 2011, pp.1-5

[8] Meejoung Kim, Seung-Eun Hong, Yongsun Kim, and Jinkyeong Kim, "Analysis of Resource Assignment for Directional Multihop Communications in mm-Wave WPANs," ETRI Journal vol.35, no.1, pp. 120-130, Feb. 2014.

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