Automatic Planning of 300-GHz-Band Wireless Backhaul Link Deployment in Metropolitan Area

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Abstract - **In 6G mobile wireless system, terahertz (THz) wireless backhaul links with high density deployment are required. However, it is difficult to deploy a lot of THz wireless links with high density in metropolitan area, because THz wireless link requires a line of sight. This paper proposes an algorithm for automatic planning of 300-GHz-band wireless backhaul link deployment. The algorithm consists of two steps; Selecting the pair of adjacent cells that can get a line of sight, and Deployment of base stations. We succeeded in the automatic planning of 300-GHz-band wireless backhaul link deployment in Shinjuku area in Japan by using this algorithm. We conducted radio wave propagation simulation of the wireless backhaul links, and showed that signal-to-noise ratio (SNR) of 99.5 % of the wireless backhaul links deployed by using this algorithm exceeds the standard demand SNR for 100-Gbit/s data transmission even when the rain rate is 100 mm/hr.**

Keywords — **6G, wireless backhaul, terahertz, base station.**

I. INTRODUCTION

In 6G mobile wireless system, ultra-high speed, high capacity, and improvement in the reliability of wireless communications are pursued. Therefore, it is ideal to communicate at as close a distance and in an unobstructed environment as possible [1]. To achieve this, ultra-high-density small cell sites are required. Moreover, the data rate of backhaul links will become over 100 Gbit/s in 6G network. The use of terahertz (THz) band has been investigated in order to achieve over 100-Gbit/s wireless backhaul link. However, it is difficult to deploy THz-band wireless backhaul links with high density at the metropolitan area, such as Shinjuku in Japan, where skyscrapers of different heights are concentrated. EU-Japan joint project “ThoR” works to develop 300-GHz-band wireless backhaul links that achieve over-100-Gbit/s data rate [2], and to develop algorithms for automatic planning of 300-GHz backhaul links [3]. In this paper, we investigated the automatic planning algorithm for 300-GHz-band wireless backhaul link deployment in Shinjuku area.

II. AUTOMATIC PLANNING ALGOLITHM

Figure 1 shows the flow diagram of the automatic planning of 300-GHz-band wireless backhaul link deployment. In this study, a 250 m x 250 m area at Shinjuku, Japan was divided into 25 (5 x 5) small cells. Each cell size is 50 m x 50 m.

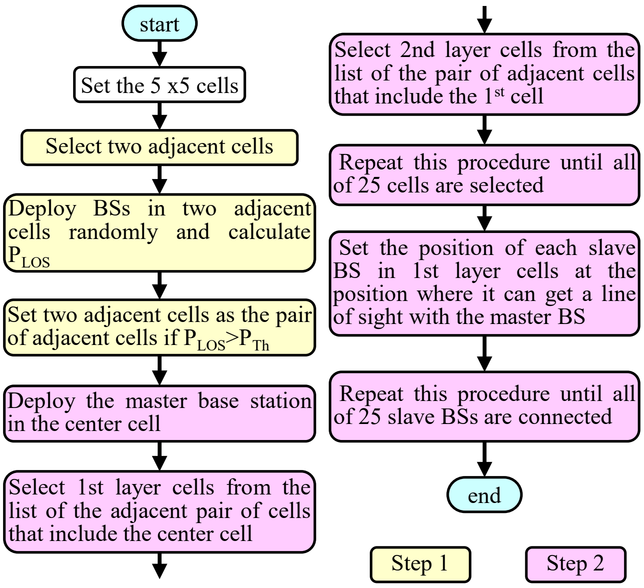
The algorithm consists of the following two steps:

Step 1: Selecting the pair of adjacent cells that can get a line of sight

In metropolitan area, skyscrapers often prevent the line-of site between base stations (BSs) installed on the rooftops of the buildings, which disables the connection between BSs in adjacent cells. In this step, BSs are randomly deployed on the rooftops in the adjacent two cells, and the probability of getting a line of sight between two BSs (P_{LOS}) is calculated. We set these two adjacent cells as the pair of adjacent cells in case P_{LOS} exceeds the threshold value (P_{Th}) we set.

Step 2: Deployment of base stations

A master BS is set on the rooftop of the building in the center cell. We select the 1st layer cells from the list of the pair of adjacent cells that include the center cell. Then, we select the 2nd layer cells from the list of the pair of adjacent cells that include the 1st layer cells. We repeat this procedure until all of 25 cells are selected. Once we have decided on the order of connections from the center cell to all cells at the ends, we set the position of each slave BSs in the 1st layer cells to the position where a line of sight with the master BS is obtained. Next, we set the position of each slave BS in the 2nd layer cells with the same procedure. We repeat this procedure until all of 25 slave BSs are connected.



We set 10 scenarios of 300-GHz-band backhaul link deployments using the algorithm shown in Fig. 1. Figures 2 show an example of the automatically planned 300-GHz-band wireless backhaul link sinario at Shinjuku. The master BS indicated by red circle is set at the rooftop of the building shown in the middle of Fig. 2. The master BS and the slave BSs indicated by the blue circles are set at the height of 5 m from the rooftop of each buildings. In the scenario shown in Fig. 2, every slave BS can connect with the master BS within 3 hops. Table 1 shows the number of hops required to connect all slave BSs in the simulated 10 deployment scenarios. All of the slave BSs can be connected with the master BS within 4 hops, and 78 % of the slave BSs can be connected with the master BS within 2 hops. 22 % of the slave BSs can not be connected with the master BS within 2 hops because some of adjacent two cells can not get a line of sight due to the buildings and are not selected as the pair of the adjacent cells.

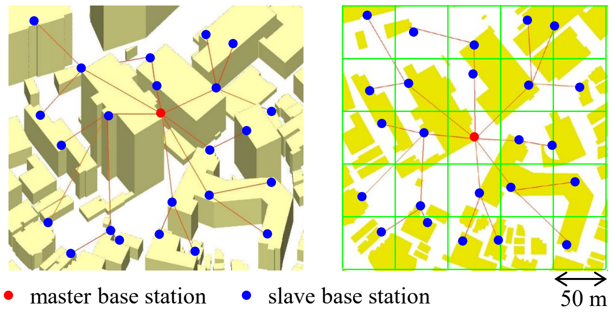


Fig. 2 Examples of the automatically planned 300-GHz-band wireless backhaul links in Shinjuku.

Table 1 Number of hops required to connect all slave BSs with the master BS in 10 deployment scenarios.

Number of hops	Number of slave BS
1	64
2	124
3	44
4	8
Total	240

III. SNR OF 300-GHZ-BAND WIRELESS BACKHAUL LINKS

We simulated the received power of the 300-GHz-band wireless backhaul links using the radio wave propagation simulator (Wireless Insite) that employs the building models at Shinjuku and calculated the cumulative distribution of signal-to-noise ratio (SNR) of the 300-GHz-band wireless backhaul links as a parameter of rain rate. The specification of the 300-GHz-band wireless backhaul link used in the simulation is determined based on the target specification of the 300-GHz-band wireless backhaul links in the ThoR project (Table 2) [4]. We employed the measured radiation pattern results of a 300-GHz-band Cassegrain antenna [5].

In Fig. 3, the impact of various weather conditions on the resulting SNR in these scenarios is presented. In the 300-GHz-band wireless backhaul link system shown in Table 2, the standard demand of SNR for 100-Gbit/s data transmission is 22 dB [3]. These results indicate that SNR of 99.5 % 300-GHz-band wireless backhaul links deployed in these 10 scenarios exceeds the standard demand SNR for 100-Gbit/s data transmission even when the rain rate is 100 mm/hr.

Table 2 Specification of the 300-GHz-band wireless backhaul link used in the propagation simulation.

Parameter	Value	Remarks
Tx power [dBm]	5	
Data rate [Gbaud]	BW/1.2	due to 20% roll-off,
Modulation	64-QAM	
NF [dB]	10	T=300 K
Antenna Gain [dBi]	50	both TX and RX
Payload Rate	0.9	both TX and RX

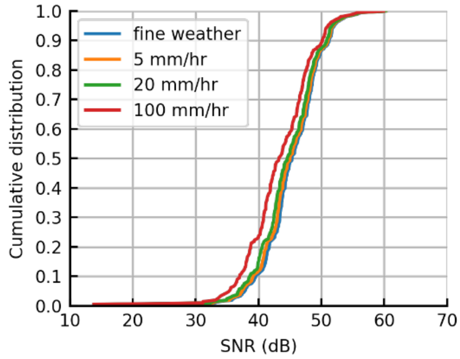


Fig. 3. SNR of 300-GHz-band wireless backhaul links deployed using the algorithm shown in Fig. 1 as a parameter of rain rate.

IV. CONCLUSION

We proposed an algorithm for automatic planning of 300-GHz-band wireless backhaul link deployment. The algorithm consists of two steps; Selecting the pair of adjacent cells that can get line of sight, and Deployment of BSs. We set 25 small cells at Shinjuku, Japan, and the cell size is 50 m x 50 m. All of the slave BSs can be connected with the master BS within 4 hops, and 78 % of the slave BSs can be connected with the master BS within 2 hops. We conducted propagation simulation of the wireless backhaul links, and showed that SNR of 99.5 % of the wireless backhaul links deployed in these scenarios exceeds the standard demand SNR for 100-Gbit/s data transmission even when the rain rate is 100 mm/hr.

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