Local 5G Received Signal Power Measurement in Presence of Building

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Abstract—**The local (private) 5G networks are now getting a lot of attention, since it can offer the secure and flexible network by the cellular-based technologies at the private facilities. This paper evaluates the received signal strength indicator (RSSI) performance of the local (private) 5G system employing the 4.8499 GHz frequency band. Measurements with the size of $50\,\mathrm{m} \times 20\,\mathrm{m}$ were set at a location between several buildings. The base station (BS) is installed inside and outside the building and the user equipment (UE) moves around the BS in the presence of buildings. The measurement results show that RSSI values differ by about 10 dB due to the penetration loss of the walls. Furthermore, the RSSI values are significantly degraded when changing from the line-of-sight (LOS) environment to the non-line-of-sight (NLOS) environment.**

I. INTRODUCTION

The fifth mobile communication system (5G) commercial services have been launched around the world. Global 5G mobile subscriptions are projected to reach 1.6 billion by the end of 2023. Furthermore, 5G will become the dominant mobile access technology by subscription in 2028. Global 5G subscriptions are forecast to exceed 5.3 billion in 2029 [1]. The 5G system can support three diverse usage scenarios: enhanced mobile broadband (eMBB), ultra-reliable and low latency communications (URLLC), and massive machine type communications (mMTC) [2].

In addition to the public 5G networks, which telecommunications carriers operate, the local (private) 5G networks [3], [4] are now getting a lot of attention [5], [6], [7]. Compared to the Wi-Fi network, which is the now natural option for the private network, the local 5G networks can offer the secure and flexible network by the cellular-based technologies [8], [9]. It can guarantee coverage at their facility (factories, agricultural lands, and indoor, etc.), even if the public networks do not exist. It can determine the user connection, resource utilization, and priority. The companies can control their own security to ensure that sensitive information doesn't leave the premises.

Cell planning is crucial when constructing a high-quality local 5G network in a private space, such a factory site. In order to establish the optimal local 5G network, it is crucial to obtain the spatial distribution of the received signal power, throughput, and so on. Therefore, this paper evaluates the spatial distribution of the received signal strength indicator (RSSI) at Kagawa University's Hayashi-cho campus. The measurement area was chosen to be surrounded by buildings, and the local 5G base station (BS) was located at the end of a corridor between the buildings. global navigation satellite system (GNSS) was installed on the cart together with a user equipment (UE) to acquire position information. The spatial distribution of received power was measured by moving the cart through the measurement area.

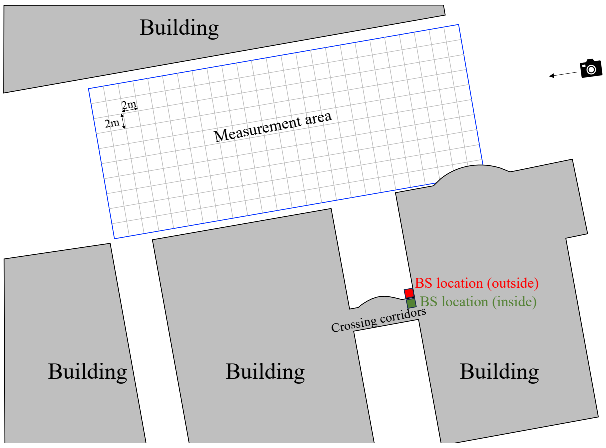
The remainder of this paper is organized as follows: Section II provides a measurement setup, followed by measurement results in Section III. Finally, Section IV presents the conclusion.

II. MEASUREMENT SETUP

The measurement was carried out at Kagawa University's Hayashi-cho campus, which is located in Takamatsu city in Japan. Figure 1(a) shows a map of the locations where measurements were performed in this paper. In addition, Figure 1(b) shows a photograph of the measurement area, taken from the position of the camera icon in Figure 1(a), looking in the direction of the arrow.

As shown in the figure, the measurement area ($50\,\mathrm{m} \times 20\,\mathrm{m}$) is a flat area surrounded by several buildings. This measurement area is further divided by a $2\,\mathrm{m} \times 2\,\mathrm{m}$ grid cell. Thus, there are $25 \times 10 = 250$ grid cells as shown in the figure. The reason for the relatively large size of the grid cells is that the area is sandwiched between buildings, and the GNSS positioning accuracy is slightly degraded compared to the typical environment. In addition, in order to evaluate the effects of shadowing and path loss, multipath fading variation is averaged over the grid cell sufficiently larger than the wavelength. Figure 2 shows the BS location in the paper. In this paper, in order to evaluate the effect of building shielding, we evaluated the received signal power performance with BS installed outside and inside a building at approximately the same location. (1) and (2) are photographs taken when the BS is installed inside, and are taken in the direction of the arrow from the position indicated by the camera icon on the map. (3) shows the case where the BS is installed outside, and the location and direction are indicated by the icon and arrow. As can be seen from the figure, the two BS locations are separated by a wall, but there is a large window right next to them.

We employed ABIT cooperation AU-510 [10] for BS as shown in Fig. 3. Table I shows the specification of the local 5G. It follows the semi-synchronous time division duplex (TDD) system (see Section 7.1.1 in [11]). To this end, the GNSS was connected to the BS. One antenna transmission and two antenna diversity reception are used. The transmission bandwidth is 100 MHz, and the number of resource blocks (RBs) is set to 264.



(a) Map of measurement area.

(b) Photograph of measurement area (taken from the position of the camera icon in Figure 1(a), looking in the direction of the arrow).

Fig. 1: Measurement area.

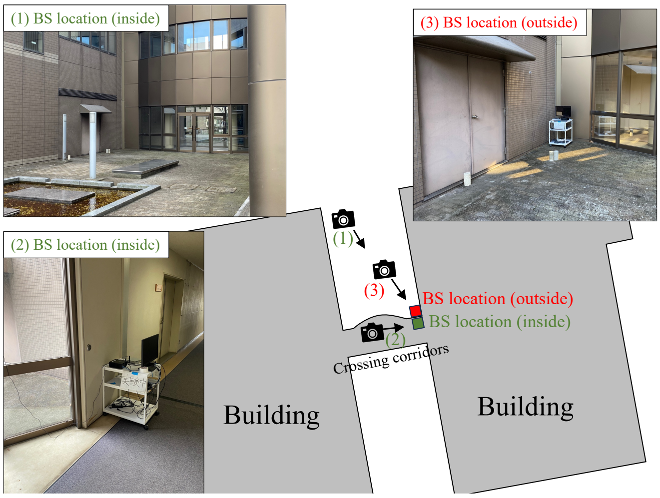


Fig. 2: BS location.

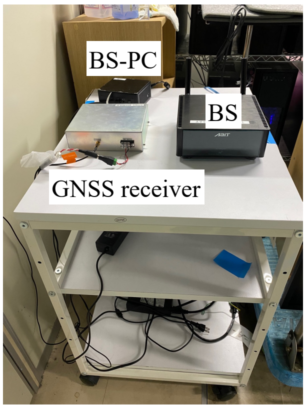


Fig. 3: Photograph of BS.

Figure 4 shows photograph of UE. A local 5G UE is connected to a UE-PC installed on top of the cart. We use SparkFun Electronics GP-20U7 [12] as GNSS module. A Raspberry Pi zero connected to GNSS is also installed to acquire location information at every 5 seconds.

Figure 5 schematically illustrates the experimental setup. The wireless performance, e.g., RSSI of the local 5G can be obtained via the Web application programming interface (API), and these values are obtained by the BS-PC connected to the local 5G BS. The wireless performance is updated every second. In addition, the location information acquired by the Raspberry Pi is transmitted to the LoRa-PC via the LoRa module[1]. Please refer to [14] for information on how to acquire location information with the LoRa module. The location information and local 5G wireless performance are acquired on different PCs, and by synchronizing the time between the PCs, the location and reception performance are precisely matched. In principle, the speed of the cart is slow enough to be accurately matched by this measurement method. Furthermore, measurements were made many times to obtain multiple reception points in the same grid cell, and the received power in the grid cell was averaged.

III. MEASUREMENT RESULTS

Figure 6(a) shows the measurement results when the BS is located outside of the building. In the figure, the colors indicate the received power intensity, with red indicating high received power and blue indicating low received power values. The RSSI in the line-of-sight (LOS) environment is relatively higher than that in the non-line-of-sight (NLOS) environment. Specifically, the right end of the NLOS environment recorded a RSSI of approximately -60 dB to -70 dB, while the center

TABLE I: Local 5G specification.

Name	Values
Carrier frequency	4.8499 GHz
Bandwidth	100 MHz (264 RBs)
Maximum transmission power	23 dBm
Duplex	TDD
Subcarrier spacing	30 kHz

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[1] We employed LoRa ES920LR based on SEMTECH SX1276 [13].

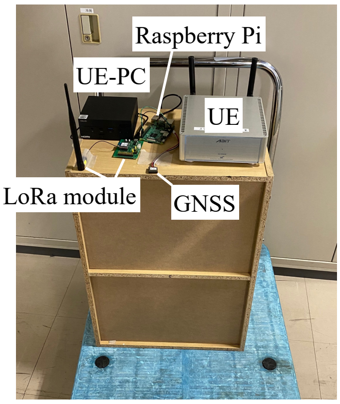


Fig. 4: Photograph of UE.

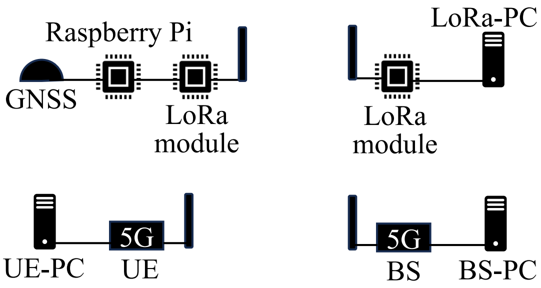


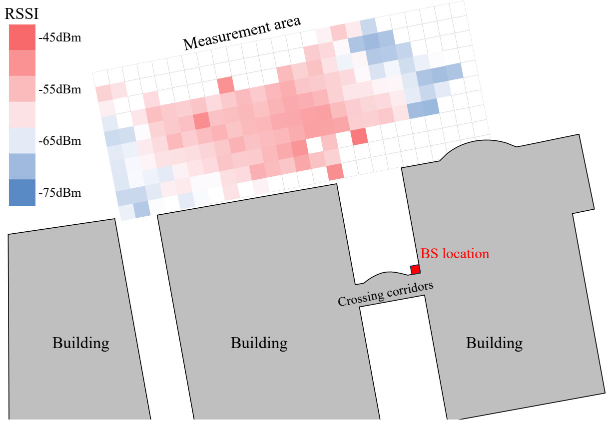
Fig. 5: Schematic illustration of experimental setup.

of the LOS environment recorded a RSSI of approximately -45 dB to -55 dB.

Next, Figure 6(b) shows the measurement results when the BS is located inside of the building. The color is same as that in Fig. 6(a). Similar to the previous result, the RSSI is relatively higher in the LOS environment than in the NLOS environment. Compared to the case where the BS was installed outdoors, the RSSI was about 10 dB lower. This is due to a decrease in received power caused by the walls of the building (penetration loss).

IV. CONCLUSION

This paper evaluated the RSSI performance of the local (private) 5G system. Measurements with the size of $50\,\mathrm{m} \times 20\,\mathrm{m}$ were set at a location between several buildings. The BS is installed inside and outside the building and the UE moves around the BS in the presence of buildings. The measurement results show that RSSI values differ by about 10 dB due to the penetration loss of the walls. Furthermore, the RSSI values are significantly degraded when changing from the LOS environment to the NLOS environment.



(a) BS location (outside).

(b) BS location (inside).

Fig. 6: Measurement results.

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