Visibility State Analysis for Base Station Cooperated Micro-cellular System

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1. Introduction

Base station (BS) cooperation technologies are expected to improve user throughput at the cell edges in a cellular system [1]-[3]. Since the performance of a BS cooperation method depends on the condition of the propagation channel, especially the difference in the received signal strengths from surrounding BSs, it is important to investigate the transitions of the signal strengths at a mobile station (MS) when evaluating the performance of a BS cooperation system taking the mobility of MSs into consideration. In a micro-cellular system, the propagation loss of the BS-MS link strongly depends on the BS visibility, that is, whether BS is in line-of-sight (LOS) or non-line-of-sight (NLOS) from the MS.

In this paper, we estimated the visibility state using three-dimensional maps of several areas and analyzed the statistics of the estimation results.

2. Visibility Estimation Method

The number of visible BSs was estimated using ray-trace simulation with three-dimensional maps containing the building data. Six areas 400 m square considered as typical urban areas were selected as the simulation models. Table 1 summarizes the characteristics of the areas. The number of visible BSs was estimated every 10m along all the roads in each area. The antenna height of each BS was 7.5m from the rooftop of the building. Figures 1 (a) and (b) show three-dimensional map examples in Ikebukuro-1 and Ikebukuro-2. The symbols A1, B1, C1 (Case 1), A2, B2, C2 (Case 2) in Figs. 1(a) and (b) indicate the locations of BSs. Figures 2 and 3 are maps showing the number of visible BSs in Ikebukuro-1 and Ikebukuro-2, respectively. Figures 2(a) and (b) show the results for Case 1 and Case 2 in Ikebukuro-1, respectively. Figures 3(a) and (b) are those for Ikebukuro-2. The figures show that the distribution of the number of visible BSs differs depending on the BS locations. Table 2 summarizes the percentages of observed points for the number of visible BSs.

3. Analysis of Visibility State

Based on the visibility estimation results, we derived the “visibility state hold distance (VSHD)”, within which the number of visible BSs remains constant. This distance is important from the viewpoint of evaluating the performance of a BS cooperation system. To obtain the statistical characteristics of the VSHD, the route of a moving MS was derived assuming that MS decides the direction in a random manner at the intersection.

3.1 Dependency on base station location

The visibility is affected by the location of BSs as shown in Figs. 2 and 3. Figure 4 shows the probability of occurrence of the VSHD. Figures 4(a) and (b) show the comparisons between the location of the BS, Case 1 and Case 2, in Ikebukuro-1 and -2, respectively. The results for Case 1 and Case 2 are indicated with a solid line and dotted line, respectively. The horizontal axis indicates the distance, and the vertical axis indicates the ratio of occurrence that the VSHD exceeds the value of the horizontal axis. Figure 4(a) shows that the curves in each visible BS have a similar tendency. In Fig. 4(b) the tendency is almost the same for the case where the number of visible BSs is 1. On the other hand, in Fig. 4(b), where the number of visible BSs is 0, the difference between the two curves is comparatively large when the VSHD is large. For this reason, the street orientation with respect to the direction of BS, street angles, may be influenced each figure of VSHD. Therefore more data are necessary to clarify the dependency of VSHD on the location of BSs.

3.2 Comparison of Simulated Areas

The probability of occurrences of the VSHD was evaluated for six areas. Figures 5(a) and (b) show the comparisons of those probabilities in six areas where the number of visible BS is 0 and 1, respectively. The figures show that the VSHDs where the number of visible BSs is 0 (Fig. 5(a)) is longer than those where the number of visible BSs is 1 (Fig. 5(b)) in all areas. In this paper, the results for the case where the number of visible BSs is more than 2 were omitted because the number of data samples is not sufficient for statistical analysis.

It is clear that the dependence on the area is significant for the probability of the VSHD. Thus it is considered that some environmental parameters, such as the average and the variance in building height, the spaces between the buildings and so on, affect the VSHD characteristics. Figure 6(a) shows the probability that VSHD exceeds 50 or 100 m against the average building height in each area where the number of visible BSs is 0, and Fig. 6 (b) shows the probability that VSHD exceeds 50 m plotted against the average building height in each area where the number of visible BSs is 1. Figure 6 (a) and (b) indicate that the average building height is one of the key parameters which define the VSHD characteristics because the probability seems to be positively correlated with the average building height when the number of visible BSs is 0 or 1.

3.3 Study Items

The parameters that influence VSHD is being investigated by analyzing more simulation data. In particular, the relation between the locations of the BSs will affect the ratio where the number of BSs is more than two, as can be expected from Fig. 2(a) and (b). In this paper, the visibility of BSs was estimated every 10 meters along the road, and the most frequent VSHD was also 10 meters. Thus, the estimations with higher resolution are necessary for more accurate analysis.

4. Conclusion

In this paper, the number of visible BSs was investigated based on the results of simple ray-trace simulations using three-dimensional maps. The VSHD characteristics were derived based on the simulation results for 6 areas, and their probabilities of occurrence were compared.

The results of the comparisons indicated that the average building height is one of the key parameters for the VSHD statistics. Also the street angle seems to be one of the influential parameters, thus more simulations and analysis are necessary to identify all the influential parameters.

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References

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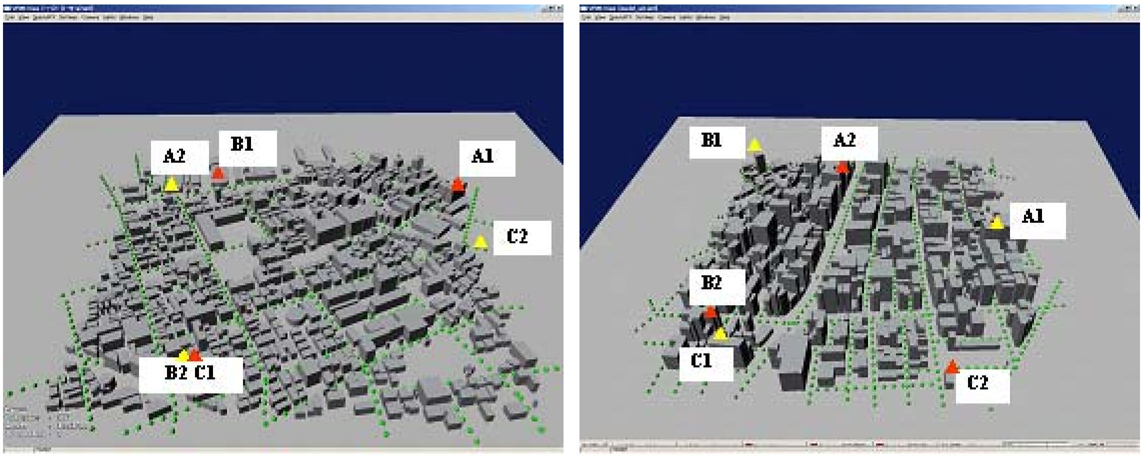
Table 1: Characteristics of the simulated areas.

	Ikebukuro			Shinjuku		
	1	2	3	1	2	3
Number of buildings	722	607	441	443	630	385
Average building height [m]	9.4	19.2	19.2	13.0	13.5	19.8
Standard deviation of building height [m]	2.8	10.8	11.8	11.8	9.3	10.7

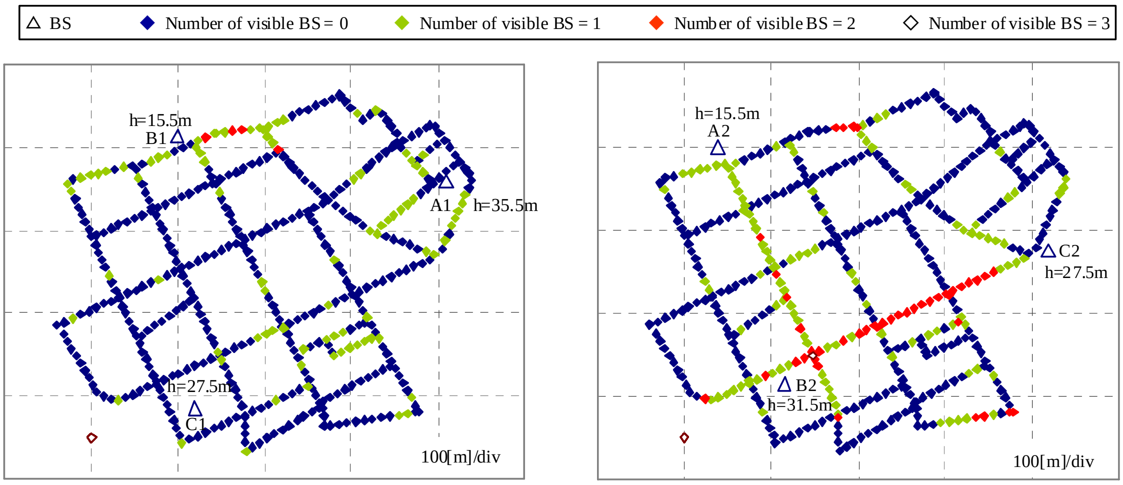
Table 2: Percentage of observed points for the number of visible BSs [%].

Number of visible BSs	Ikebukuro					Shinjuku		
	1		2		3	1	2	3
	Case 1 (Fig. 2(a))	Case 2 (Fig. 2(b))	Case 1 (Fig. 3(a))	Case 2 (Fig. 3(b))				
0	79.9	65.5	86.5	80.5	77.5	81.9	84.8	87.2
1	19.2	24.7	13.3	18.7	20.7	15.6	14.9	12.5
2	0.9	9.6	0.2	0.8	1.8	2.5	0.3	0.3
3	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0



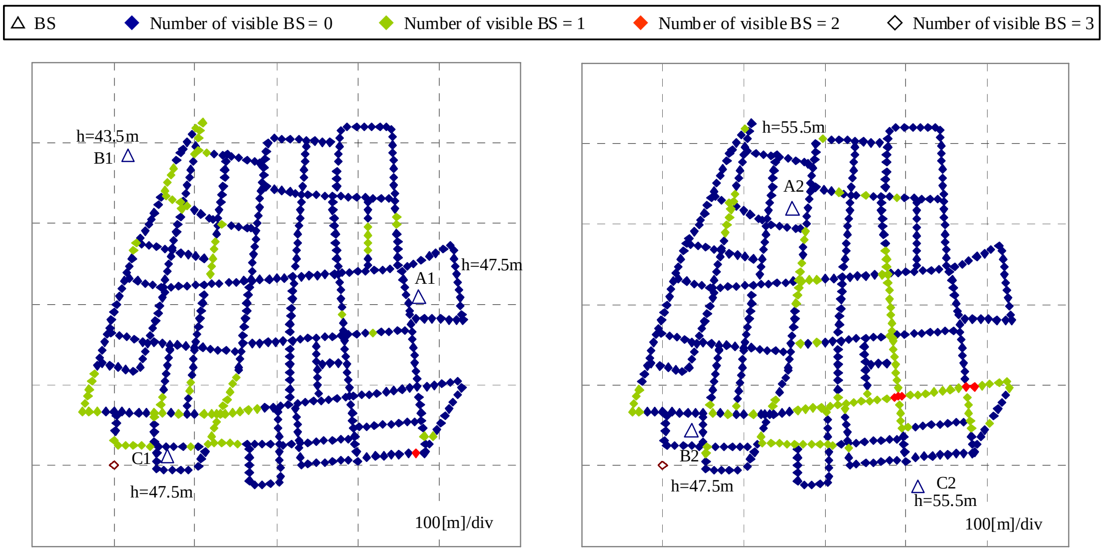
(a) Ikebukuro-1 (b) Ikebukuro-2

Figure 1: Samples of three-dimensional maps used for the visibility estimation.



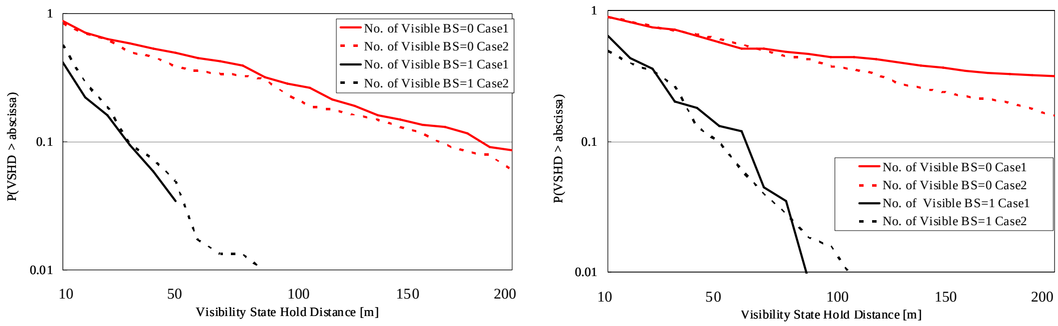
(a) Case 1 (A1, B1, C1) (b) Case 2 (A2, B2, C2)

Figure 2: Maps of the number of visible BSs in Ikebukuro-1.



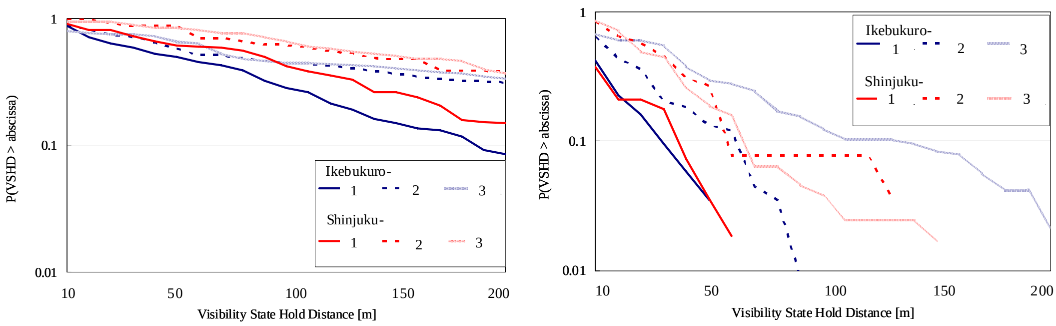
(a) Case 1 (A1, B1, C1) (b) Case 2 (A2, B2, C2)

Figure 3: Maps of the number of visible BSs in Ikebukuro-2.



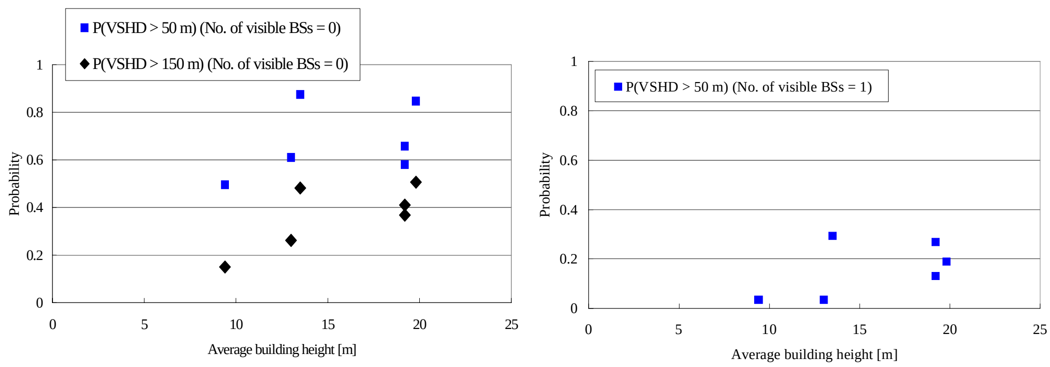
(a) Ikebukuro-1 (b) Ikebukuro-2

Figure 4: The probability of occurrence of the VSHD.



(a) Number of visible BSs = 0 (b) Number of visible BSs = 1

Figure 5: The probability of occurrence of the VSHD in six areas.



(a) Number of visible BSs is 0 (b) Number of visible BSs is 1

Figure 6: The probability of VSHD plotted against the average building height in each area.