Effective Method of Pathloss Fitting with Azimuth Variable for White Space Boundary Estimation

Kenshi Horihata[1], Issei Kanno[1], Akio Hasegawa[1], Toshiyuki Maeyama[12], and Yoshio Takeuchi[1]
[1]Advanced Telecommunications Research Institute International (ATR) / [2] Takusyoku University
[1] 2-2-2, Hikaridai, Seika, Soraku, Kyoto, 619-0288, Japan / [2]815-1, Tatemachi, Hachioji, Tokyo, 193-0985, Japan

Abstract – **This paper proposes a method of pathloss fitting by deciding the prediction formula as a function of azimuth, which is centered at a transmission source of incumbent system. We are studying the framework of white space boundary estimation with a smaller number of sensors. The framework decides the white space boundary by estimating coverage of incumbent radio systems with positions of transmission sources and predicted pathloss. To realize high accuracy estimation of white space boundary, a sophisticated method of pathloss fitting with a smaller number of sensors is required. The proposed method decides the prediction formula continuously for every azimuth with utilizing sensing data efficiently to meet the requirements.**

Index Terms — **azimuth variable, pathloss prediction, radio environment map, white space boundary**

I. INTRODUCTION

Recently, frequency resources are insufficient because mobile data traffic by smart phones is increased rapidly. The spectrum which is not used geologically and/or temporally by incumbent radio systems (IRSs) is called as white space (WS). If WSs can be shared among radio systems, the situation can be alleviated.

WS boundary (WSB) indicates the boundary between IRS coverage and WS area. The accurate WSB information is required to utilize WS effectively. The current utilized WS (e.g. TV WS [1]) decides the WSB by WS database which has no detailed information about radio propagation depending on each environment such as buildings and the ground, in IRS coverage. Hence, it is not sufficient to decide WSB accurately. The detailed radio propagation information can be obtained by many sensors or a huge number of drive tests, this is not realistic by cost and arrangement time.

We are studying the framework of WSB estimation with smaller number of sensors [2]. The framework decides WSB by estimating coverage of incumbent radio systems with positions of transmission sources (emitters) and predicted pathloss. In the framework, we define "pathloss fitting" as decision of pathloss prediction formula based on signal strength data of sensors and distance from an emitter to the sensors. For accurate WSB estimation, pathloss fitting is needed to reflect the propagation characteristics around an emitter. An accuracy of pathloss fitting is related to both a resolution of azimuth centered at an emitter and the number of sensors used for the fitting. With a smaller number of sensors, a higher azimuth resolution decreases the accuracy because the number of sensors used for the fitting of each azimuth is relatively reduced. For the issue, this paper proposes an efficient method of pathloss fitting with "azimuth variable", which utilizes sensing data effectively and is discussed in section II.

II. PATHLOSS FITTING WITH AZIMUTH VARIABLE

As a pathloss fitting method with a high azimuth resolution, the following method had been considered. The prior method is that all the deployed sensors are segmented by a specific width of azimuth centered at the emitter, as shown in Fig.1 (a). The pathloss fitting is performed with sensing data in every segment by approximating the coefficients a, and c of the following equation.

$$y_{Sn} = a \log x_{Sn} + c \tag{1}$$

y_{Sn} is the predicted pathloss in segment Sn which can be calculated by substituting a specific distance from the emitter x_{Sn}. Concretely, the coefficients are decided based on least squares (LS) method with the data set of signal strength measured in a sensor and distance from the emitter to the sensor. The cost function E_{Sn} for the LS can be written in,

$$E_{Sn} = \sum_{i=1}^{N_{S_n}} (P_i - c - a \log r_i)^2 \tag{2}$$

where, P_i and r_i are signal strength and distance from the emitter to sensor i. Since unexpected values of a, c may be obtained from (2) if the number of sensors in Sn, N_{Sn}, is smaller, the accuracy of pathloss fitting may decrease.

Proposed method does not segment sensors explicitly and processes pathloss fitting with sweeping the reference azimuth as shown in Fig.1 (b). For the purpose, "azimuth variable" $a(\theta_k)$, $c(\theta_k)$ is introduced to the pathloss fitting as,

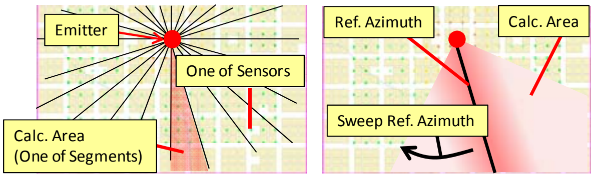
$$y_{\theta_k} = a(\theta_k) \log x_{\theta_k} + c(\theta_k) \tag{3}$$

where, $y_{\theta k}$ and $x_{\theta k}$ are predicted pathloss and distance from the emitter for a reference azimuth θ_k. The coefficients $a(\theta_k)$, $c(\theta_k)$ are decided by weighted LS method of which cost function is defined as,

$$E_k = \sum_{i=1}^{N} f(\theta_i) \cdot (P_i - c(\theta_k) - a(\theta_k) \log r_i)^2 \tag{4}$$

$$f(\theta_i) = \alpha^{\frac{|\theta_k - \theta_i|}{\beta}} \tag{5}$$

where, N is a total number of sensors, $f(\theta_i)$ is weight of LS, which is defined by forgetting factor α and azimuth resolution factor β. Factor α takes a value within the range of $0 < \alpha < 1$ and Factor β takes a value within the range of $0 < \beta$



(a) Prior method (b) Our proposed method

Fig. 1. Overview of prior and our proposed method

$\leq \pi$. Eqs (4) and (5) means that it is calculated with signal strength data of sensors in a wide area, and the importance of the data is decided by the angle between their azimuth and the reference azimuth. Since a lot of data of sensors can be used as samples for the pathloss fitting, it can be expected that the accuracy of pathloss fitting is improved.

III. SIMULATION RESULTS

In order to verify the effectiveness of the proposed method, computer simulations were carried out. At first, received signal power data is generated by Ray-trace simulation so as to make the reference environment shown in Fig. 2. The size of analytical field was defined by 5 km square and that was divided by 50 m square mesh, and received signal power data is generated in each mesh as reference mesh data. In addition, it assumed the sub-urban area and square-block type buildings were modeled with statistical information opened by Japanese government. The position of the emitter was set in the center of the field, and on intersection of the roads along both lines of north-south and east-west. Hence, the received signal powers of the sensors on the road were high because of the line of sight propagation. The antenna directivity of the emitter is toward 30 degrees from the north (the north-northeast).

In the same analytical field, pathloss fitting based on prior and proposed method were performed with a reduced number of sensors of which received signal powers are also generated by Ray-trace. The boundary of which received signal power corresponding to specific values are plotted per 10 dBm and the plotted colors are the same as that of Fig. 2. Figs 3 (a) and (b) show the results with 625 sensors, which are deployed in every 200 m mesh. In Fig. 3 (a), the result of the prior method is not stable because the boundary of some segments yields outlier. The cause of the unstable results can be considered as the shortage of the samples in the segment. Contrary, as shown in Fig. 3 (b), the result of the proposed method is closer to the reference compared to that of the prior method. Fig. 4 shows the root-mean-square error (RMSE) between the reference and the predicted received power from pathloss fitting. For calculating the RMSE, an area of which azimuth is within 5 degrees was defined as one unit. And in each unit, the data of the reference meshes which were 1.5 km plus-minus 100 m from the emitter was used. The proposed method has around 10 dB errors at every unit, but the prior method has over 20 dB errors in some units.

These results show that the proposed method can characterize the propagation well even with a reduced number of sensors by utilizing sensing data effectively.

IV. CONCLUSION

This paper proposes the azimuth variable pathloss fitting to characterize pathloss with higher accuracy even with a reduced number of sensors and shows its effectiveness. Optimization of the parameters such as the weight through the evaluations, and introduction of other variables will be future works. It is noteworthy that, the proposal method to estimate pass loss with higher accuracy, is beneficial not only for identifying the WS but also for other various applications as discussed in the research field of radio environment map [3], with the flow of big data trends.

ACKNOWLEDGMENT

This research was performed under “Research and Development on Technology to Accelerate Effective Utilization of Local White Space using Radio Environment Big Data”, in the Strategic information and Communications R&D Promotion Program (SCOPE) funded by Ministry of Internal Affairs and Communications, Japan.

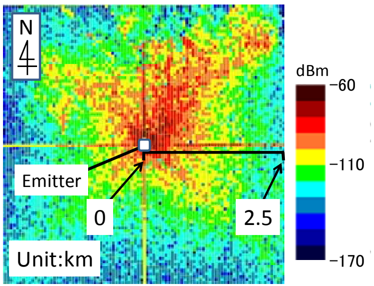
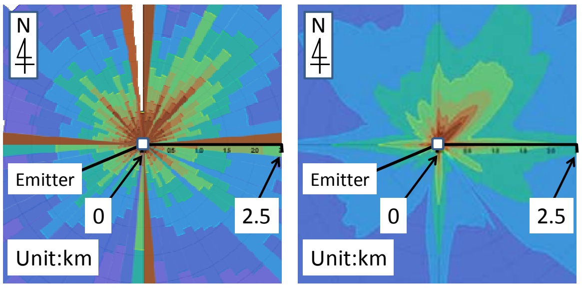


Fig. 2. Reference Environment (8282 points, 50 m Mesh).



(a) Prior Method (b) Proposed Method

Fig. 3. The Results with 625 Sensors (200 m Mesh).

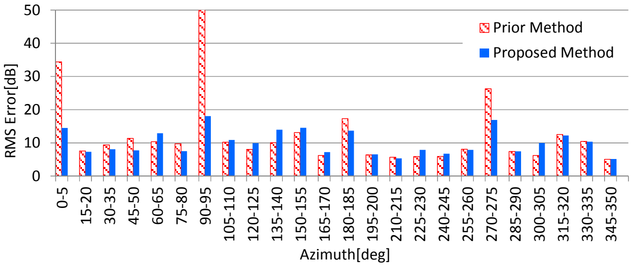


Fig. 4. Error Comparison between Two Method.

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