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

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\textbf{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 and predicted pathloss. To realize high accuracy estimation of incumbent radio systems with positions of transmission sources (emitters) and predicted pathloss. To realize high accuracy estimation of incumbent radio systems with positions of transmission sources (emitters) and predicted pathloss.

\textbf{Index Terms} — azimuth variable, pathloss prediction, radio environment map, white space boundary

\section{I. INTRODUCTION}

Recently, frequency resources are insufficient because mobile data traffic by smart phones is increased rapidly. The spectrum which is not used geographically 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.

\section{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.

\[ y_{Sn} = a \log x_{Sn} + c \]  

\( y_{Sn} \) 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,

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

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” \( a(\theta_i), c(\theta_i) \) is introduced to the pathloss fitting as,

\[ y_{\theta_i} = a(\theta_i) \log x_{\theta_i} + c(\theta_i) \]  

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

\[ E_\theta = \sum_{i=1}^{N} f(\theta_i) \cdot (P_i - c(\theta_i) - a(\theta_i) \log r_i)^2 \]  

\[ f(\theta_i) = \alpha^{-\beta} \]  

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

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