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Efficient White Space Boundary Estimation with Heterogeneous Types of Sensors

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Abstract – **This paper proposes a novel framework for white space (WS) boundary estimation which utilizes heterogeneous types of sensors. The proposed framework utilizes sensors not for spectrum sensing, but for estimating the propagation parameters that characterize the boundary to the incumbent radio systems (IRSs) to identify WS efficiently. The position of IRS emitter (transmission source), its transmission power, and pathloss around it are estimated to identify the boundary from collected sensing data. The former 2 parameters and latter one are estimated with sparsely deployed long-range sensors and densely deployed low-end small sensors, respectively. In addition, its result of preliminary feasibility study is described.**

Index Terms — **white space boundary, propagation characteristics, heterogeneous types of sensors, cognitive radio**

I. INTRODUCTION

Upcoming spectrum crunch requires innovative technologies for efficient utilization of limited frequency resources. One promising technology is the spectrum sharing between radio systems based on the principle of cognitive radio [1, 2]. The spectrum which is not used geographically and/or temporally by incumbent radio system (IRS) is called as white space (WS). That is the target for sharing by coexisting radio systems, and the utilization of the TV-band WS (TVWS) has been actively considered [3]. However, the WSs, which corresponds to other frequency bands, have not been considered sufficiently, despite of its potential availability. Hence, it is firstly required to actualize their available area for accelerating their utilization.

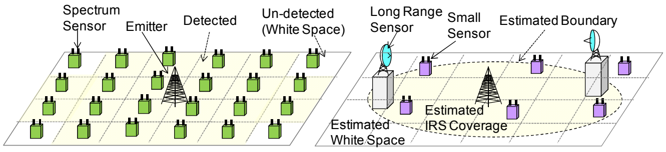
For coexisting radio system to recognize the WS efficiently, a database (WSDB) has been considered to provide information of its availability [4]. In order to construct the WSDB, estimation of the boundary between WS and IRS coverage is required. Actually, the WSDB has been operated for TVWS in U.S., and the boundary is defined with TV coverage. Concretely that is determined within the range specified by a fixed received signal level with a common pathloss prediction model [5]. This definition is efficient for global comprehension. However, it tends to over-estimate the coverage because the propagation characteristics depending on topography of each place are not taken into account. In addition, it requires the knowledge about the position of the transmission source (emitter) and its transmission power. Those are not disclosed officially in most of the radio systems. As an alternative for estimating the boundary, collection and consolidation of the spectrum sensing data can be considered. However, a large number of sensors are needed to be deployed for detecting WS with high granularity. Especially for IRSs other than TV, the higher granularity will be further required because their transmission power and coverage tend to be relatively lower and smaller. In addition, the sophisticated spectrum sensing requires high-end functionality [6] and it is not suitable for dense deployment.

This paper proposes a framework for the WS boundary estimation, targeting to general WS (not limited to TVWS), that utilizes heterogeneous types of sensors. Motivating by the requirement for higher geographical resolution with smaller number of sensors, the framework utilizes sensors not for obtaining the spectrum sensing data, but for estimating the boundary of IRS coverage. Concretely, the framework estimates position of emitter and its transmission power based on the collected data measured by long-range sensors deployed sparsely in wide range. Subsequently, it characterizes a pathloss prediction formula around the emitter with collected received signal power data measured by low-end small sensors deployed relatively-dense. The boundary is determined by consolidating the estimated parameters. The contribution of this paper is the proposal of the framework and preliminary of its feasibility confirmation.

II. FRAMEWORK OF WHITE SPACE BOUNDARY ESTIMATION

In order to explain the motivation of the proposed framework, Fig.1 shows the concepts of the boundary estimation with (a) spectrum sensors and (b) proposal. In Fig.1 (a), the deployed spectrum sensors detect existence of the IRS spectrum in each position and the IRS coverage can be identified from the grids indicating the existence. With this method, sparse sensor deployment, corresponding to the larger grid size, cannot inherently detect the smaller WS. In other words, it is difficult to detect it with higher resolution than the interval between sensors. On the other hand, the proposed framework, shown in Fig. 1 (b), estimates IRS coverage directly from the data collecting from long-range sensors and small sensors, and identifies the boundary. Hence, the detection granularity do not depends directly on the grid size (number of sensors), but on the accuracy of the boundary estimation from the limited number of sensing data.

Figure 2 shows the detailed data flow and the boundary estimation process of the proposed framework. The framework is operated in the server which collects the sensing data and it provides the estimated boundary to WSDB. The sensing data of long-range and small sensors are received signal IQ data sequence and received signal power, respectively. In addition, the server also collects and administrates the positions of all sensors. At first, the framework estimates the position of the emitter by utilizing the received signal sequence of long-range sensors. For example, TDoA (Time Difference of Arrival) based localization can be utilized by collecting the data from multiple sensors. The transmission power is estimated with the received signal power of each long-range sensor and distance from estimated emitter position to each sensor from a specific pathloss prediction formula. It is noteworthy that, the sensors should be installed in higher position to ensure LoS (Line of Sight) for accurate estimation. In the next step, the pathloss fitting approximates the coefficients of a pathloss prediction formula, which is defined as variable of distance and target frequency. The fitting characterizes the propagation environment reflecting the topography around each emitter. The received signal power data collected from the distributed small sensors and distances between the emitter and sensors are used as samples for the fitting. Finally, the IRS boundary can be calculated for determining the distance from emitter by substituting a specified received signal power for regulating WS and the target frequency into the formula with approximated coefficients.



(a) Spectrum Sensing (b) Proposed Framework

Fig.1. Concepts of WS estimation

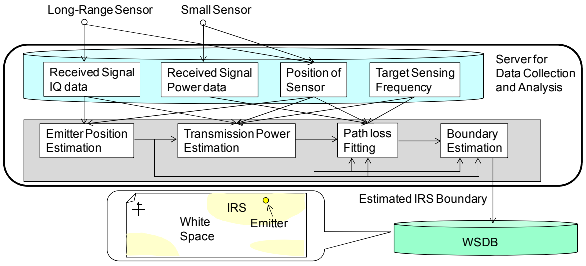
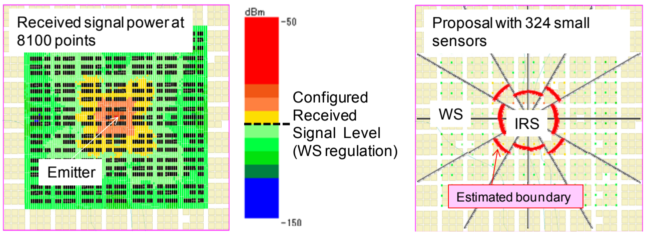


Fig.2. Data flow and detailed estimation process

III. FEASIBILITY STUDY

In order to confirm the feasibility of the boundary estimation with pathloss fitting, computer simulations were carried out. As a reference, the received signal power data in 8100 distributed positions are generated by Ray-tracing assuming urban scenario and the results are plotted in Fig.3. (a). For the same scenario, the pathloss fitting was performed with data of small sensors, and the boundary is estimated from the fitting result and configured received signal level corresponding to a WS regulation. Note that the emitter position was assumed to be ideally estimated. Concretely, 324 small sensors are assumed to be deployed at a regular interval, and their received signal powers are also generated by Ray-tracing. The configured received signal level was set to -114dBm. In Fig.3. (a), the boundary corresponds to the outline of the grids colored in yellow. Fig.3. (b) shows the results of estimated boundary drawn in the red line. For characterizing the azimuth dependency of the propagation, the fitting and boundary estimation were performed for every segment, divided by 30 degrees with a central focus on the emitter. Optimal number of segments needs for further study. From the results, it can be confirmed that the boundary was characterized well even with reduced number of sensors (4% of the points for generating the reference).



(a)Reference data (b) Estimated boundary

Fig.3. Results of feasibility study

IV. CONCLUSION

This paper presents the framework for WS boundary estimation utilizing heterogeneous types of sensors. The framework estimates the boundary by combining the IRS emitter position, transmission power, and characterized pathloss around it estimated from collected sensing data. Numerical examples show the feasibility of the boundary estimation with pathloss fitting. The consideration of the enhanced elemental techniques and detailed evaluation through simulations and measurements will be future works.

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