Development of a Smart Spectrum Access Prototype

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***Abstract*—In this poster, a concept of smart spectrum access (SSA) is shown. The SSA corresponds to an enhanced dynamic spectrum access (DSA) in which secondary users (SUs) can utilize vacant spectrum licensed to primary users (PUs). Specifically, in the SSA, SUs attempt to utilize vacant spectrum more efficiently based on the prior information about spectrum utilization by PUs. One important issue in SSA is the implementation of a function obtaining the prior information. For this issue, a two layer architecture based SSA has been proposed and it consists of the first layer corresponds to a DSA system (DSAS), and the second layer is a spectrum awareness system (SAS) which is dedicated for spectrum measurement and obtaining the prior information. In our poster, the concept of SSA, developed SAS prototype based on multiple sensors, and some developed signal processing methods for SAS are shown. The experimental results demonstrate the validity of SAS and the concept of SSA.**

I. Introduction

For solving the radio spectrum scarcity problem, dynamic spectrum access (DAS) with cognitive radio techniques has been extensively investigated. In DSA, the spectrum licensed to primary users (PUs) is shared by secondary users (SUs) while protecting the PUs from the interference caused by SUs' transmissions. To enable DSA, spectrum awareness techniques, such as spectrum sensing and geolocation database, are very important. Spectrum sensing techniques have been investigated to achieve the instantaneous spectrum awareness and the requirements for the spectrum sensing are high accuracy, low latency and low computational/implementation cost. However, it is not easy to achieve all the requirements and this is a bottleneck of realization of DSA.

One potential approach to satisfy the requirements in spectrum sensing is smart spectrum access (SSA) which is an enhanced DSA that utilizes useful prior information such as statistical information on PU spectrum usage [1]. In fact, it has been shown that using statistical information can enhance not only the spectrum sensing performance, e.g., [2], but also spectrum management and channel selection techniques [3].

One important issue for SSA is the implementation of the function obtaining the prior information in SSA. For this issue, a two layer architecture is an attractive approach, where the first layer corresponds to a DSA system (DSAS) consisting of PUs and SUs, and the second layer is a spectrum awareness system (SAS) [1]. The SAS is dedicated for spectrum measurements, modeling/estimation of spectrum usage information, and provision of the useful information obtained by the measurement to SUs. In SAS, there are several sensors are deployed and efficient signal processing for the spectrum measurement is implemented. Due to the two layers, SUs no longer suffer from the high implementation cost as the useful information is obtained and provided by the SAS.

In this poster, we focus on the two-layer SSA system and the two-layer SSA system including the concept of SSA and the developed SAS prototype are introduced. In the SAS prototype, several advanced signal processing techniques to achieve accurate spectrum measurement are implemented. Some experimental results will show the validities of the concept and the SAS prototype.

II. Two-Layer Smart Spectrum Access

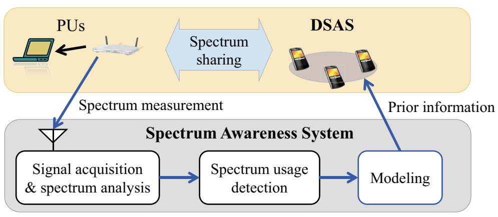

Fig. 1. Conceptual diagram of two-layer SSA

The conceptual diagram of two-layer SSA is shown in Fig. 1. In the DSAS in the first layer, SUs can utilize the spectrum while protecting the PUs from the interference caused by the SU's spectrum usage. The SAS provides useful statistical spectrum usage information to SUs based on spectrum measurements. Here, spectrum measurements include PUs' signal acquisition, spectrum analysis (e.g., estimation of power spectrum density (PSD) via fast Fourier transform (FFT)) and spectrum usage detection such as energy detection (ED). These functions are illustrated in the block diagram in Fig. 1. The signal acquisition block includes the part from the RF front-end to the analog-to-digital-converter which is responsible for

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obtaining the I-Q baseband samples. Spectrum analysis block then converts the acquired I-Q samples into PSD. Based on the PSD, spectrum usage detection block provides spectrum usage data on a two-dimensional time-frequency plane. Finally, some spectrum usage information, such as duty cycle (DC) and sojourn time, can be estimated/modeled based on the detection results.

For accurate signal detection, we have proposed proper segment size setting in Welch FFT [4]. Specifically, Welch FFT uses averaging process at the expense of frequency resolution. In fact, both of number of averaging and frequency resolution affect the performance of spectrum usage recognition. The proposed segment size setting can provide significant gain in the spectrum usage detection.

We also proposed a post-processing method for ED outputs, i.e., the spectrum usage detection [5]. The basic idea of post-processing is estimation of signal area (SA) where SA denotes the area on a time/frequency plane occupied by one continuous PU's signal, such as one data packet. In addition, we utilize false alarm (FA) cancellation to the SA estimation and it has been shown that significant gain in the spectrum usage detection is again available. One remarkable fact is that the computational cost of the SA estimation with FA cancellation is not very high, but low compared to typical approaches [6].

Based on the detection results, we can obtain behavior of spectrum usage by modeling. In the related work [7], modelings for stochastic and deterministic behaviors of DC have been proposed, respectively. In fact, we combine them to one modeling to achieve efficient modeling. Specifically, in the proposed model, the number of parameters for expressing the behaviors of DC is less than the conventional modelings.

Finally, we have shown that the spectrum sensing performance can be improved by the information in the modeling, i.e., DC. In the spectrum sensing, we have developed threshold setting to achieve target detection performance. This is important for protecting PUs.

III. SSA PROTOTYPE SYSTEM AND ITS VERIFICATION

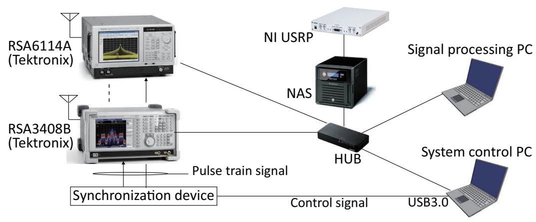

Fig. 2. SSA prototype system

Figure 2 shows the implemented two-layer SSA prototype system. In the system, multiple sensors up to four perform the spectrum measurement. Here, the synchronization device controls the measurement timing on OEs using a pulse train signal with a duty cycle given by system control PC. Each sensor performs the first function (PUs' signal acquisition) and transfers obtained data to storage device such as network attached storage (NAS). After that, signal processing PC performs the last three functions (Welch FFT, ED plus SA estimation with FA cancellation and modeling/estimation of spectrum usage information. The obtained information also are stored in storage device and their information are provided to SUs. SUs (universal software radio peripheral (USRP) in Fig. 2) perform spectrum sensing and other DSA techniques exploiting provided information.

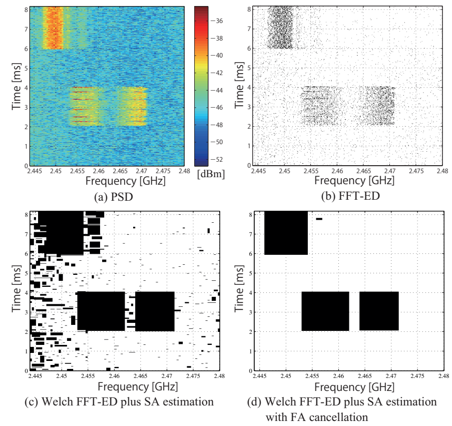

Fig. 3. Verification of SSA prototype system

Figure 3 shows several results obtained by our prototype system: (a) PSD, (b) FFT-ED, (c) Welch FFT-ED plus SA estimation and (d) Welch FFT-ED plus SA estimation with FA cancellation. From the figure, we can see that the result (d) achieves best detection accuracy. Thus, more accurate information can be provided to SUs when exploiting the result (d) rather than the results (b) and (c).

IV. CONCLUSION

In this poster, we have shown the concept of smart spectrum access (SSA) and two-layer SSA prototype system. In addition, some signal processing techniques for SAS are also introduced. Experimental results show the validity of SSA and SAS prototype.

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