AN EFFICIENT APPROACH FOR SENSING AND TRANSMISSION IN COGNITIVE RADIO WITH MINIMAL INTERFERENCE

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ABSTRACT

Spectrum sensing is an important function performed by cognitive radio to find the free spectrum or to save the primary user from interference caused by the secondary user (SU). There are two conventional spectrum sensing approaches: quiet sensing and active sensing. These conventional sensing approaches suffer from several problems. In quiet sensing, the calm period degrades the SU capacity. In active sensing, the SU capacity gets degraded by the need for additional resource consumption and the mismatch in feedback information. To overcome these problems, the structure of simultaneous PU sensing and information transmission is introduced. In this approach, the SU transmitter can sense PU signals and transmit information signals at the same time by dividing its spatial resources. Expanding on this work, by using the adaptive filter we propose a concept of "Transensing with minimal interference" which adaptively uses spatial resource according to the surrounding environments without interferences. Finally, the impact of residual interference on Transensing is minimized.

Index Terms—Cognitive radio, adaptive filter, spectrum sensing, transensing.

I INTRODUCTION

Cognitive radio is the intelligent radio that overcomes the spectrum scarcity problem occurring in wireless communication system by allowing the secondary or unlicensed users to use the spectrum of the primary user or licensed user when their spectrum is free. The free spectrum is also known as the white spectrum. Spectrum sensing is an important tool in cognitive radio for finding the white spectrum and protecting the primary user (PU) from interference. It allows the secondary user (SU) to determine the existence of the PU and use the spectrum when there is no PU signal. Conventional spectrum sensing techniques can be categorized into two types: quiet and active. In quiet spectrum sensing, the SU must stop transmitting before it performs spectrum sensing. If the spectrum is white or idle, the SU can then use it. With this approach, a quiet period for spectrum sensing is required in front of each data transmission frame.

The existence of this quiet period can reduce the potential capacity of the SU. In order to overcome this problem, several research efforts have been conducted on simultaneous sensing and data transmission in CR environments. Song, proposed an active spectrum sensing approach in which an inactive SU performs spectrum sensing while an active SU is transmitting. Unlike quiet spectrum sensing, active sensing can dispense with the quiet period anymore. Lee, proposed similar active sensing concepts where some SUs perform spectrum sensing while others receive data from a cognitive base station (BS) using Zero Forcing, so that data transmission does not interfere with the sensing SUs. Moghimi proposed simultaneous sensing and data transmission at the SU receiver using time/sub-channel division where

more SU received antennas are available. Stotas proposed a frame structure where the spectrum sensing and data transmission can be done at the same time. This is done by having the SU receiver cancel the SU Tx's signal out of the received signal using successive interference cancellation and using the remaining signals for spectrum sensing. However, several problems remain with these active sensing techniques. First, each requires additional resources. The inactive SU is forced to consume extra power in order to sense the PU signal and transmit the sensing information to the active SU. In addition, more spectrum resources are required because the sensing information needs to be fed back. Second, this feedback information may not be suitable for the active SU transmitter because the locations where the inactive SU sensing is done and where the active SU transmission occurs are different. Finally, the inactive SU suffers increased uncertainty from the interference caused by the active SU.

When the active SU interference is added to the received signal, it becomes difficult for the inactive SU to distinguish between the noise-only case and the signal-plus-noise case. The result can be degradation of the sensing performance. Tsakalaki proposed a structure to enable simultaneous communication and sensing using spatial filtering with a three-port antenna system. Expanding on this work, a concept of "TranSensing" was proposed which adaptively uses spatial resource according to the surrounding environments. This structure involves a multi-antenna system designed to exploit antenna isolation and self-interference cancellation.

We formulate an average SU capacity in terms of sensing performance and ergodic capacity. In this case, the antenna partitioning affects the SU capacity in the proposed TranSensing system. For this reason, we also propose a two-stage algorithm consisting of correlation-based antenna partitioning and conditional sensing duration control to make efficient use of TranSensing by balancing the average SU capacity and computational complexity. Then, we analyze the effect of residual self-interference on TranSensing, since the residual interference can degrade the sensing performance for TranSensing. Lastly ,we minimize the interference that occur in the transensing by using the adaptive filter.

II . EXISTING METHODOLOGY

Tsakalaki et al, proposed a structure to enable simultaneous communication and sensing using spatial filtering with a three-port antenna system. Expanding on this structure, Jihaeng Heo proposed a new structure

which involves a multi-antenna system designed to exploit antenna isolation and self-interference cancellation . This proposed TranSensing adaptively uses spatial resources according to surrounding environments. The specific procedures for the TranSensing system are as follows. First, a SU transmitter decides which antenna subsets and sensing duration to use with respect to the SU capacity and computational complexity.
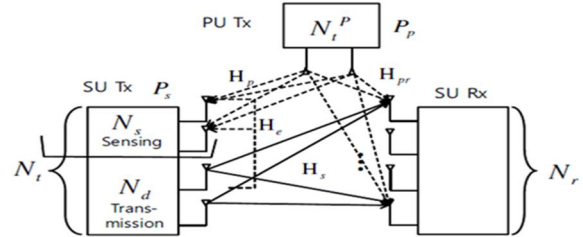

Fig1. System and channel models for transensing cognitive MIMO system

As shown in Fig 1, antennas at the SU transmitter of the transensing cognitive MIMO system are partitioned into two subsets. One subset is assigned to perform sensing and the other subset is assigned to perform transmission. Specifically, each subset consists of spatial resources in numbers of antennas Ns and Nd, respectively, where Nt = Ns + Nd. Once the antenna subsets have been determined, the first time frame is used by the SU transmitter only to sense a PU signal, because initially there is no sensing information. Based on this result, the SU transmitter uses the spectrum if the spectrum is white. Except for the first time frame, as shown in the Fig.1, the SU transmitter senses the PU signal with Ns antennas and transmits data with Nd antennas at the same time.

In this case, the proposed SU transmitter can sense the PU signal, xp, by canceling the echo signal interference, xs. An example of the frame structure for TranSensing is shown in Fig 2. Generally, any echo interference will occurs in the sensing part of the proposed SU transmitter. If the echo interference cannot be efficiently eliminated, the sensing performance could be significantly reduced because the power of the echo interference is relatively large compared to that of the received PU signal. However, when the antennas are separated into mutually exclusive transmitting and sensing antenna parts, it can be assumed that the echo interference is perfectly eliminated by insulation or subtraction of echo interference.
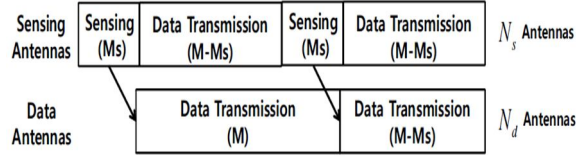
Fig2. Frame structure for a cognitive radio network with transensing

According to this frame structure, a secondary user ceases the transmission of data packets at the beginning of the each frame. Sensing will be carried out for τ seconds and the transmission will be carried out for T-τ seconds. Hence this reduces the throughput because even though the channel is free to transmit data for the second frame the continuous data transmission does not occurs. The performance of the cognitive radio network greatly depends on the spectrum sensing scheme, sensitivity, sensing time, probability of detection, and probability of false alarm

III PROPOSED METHODOLOGY

The key challenge in designing this new approach is to overcome the interference that occur in the transensing cognitive radio system. In the proposed technique, we minimize the residual interference that occur in the transensing approach by placing an adaptive filter in the secondary user receiving antennas as shown in the Fig 3.
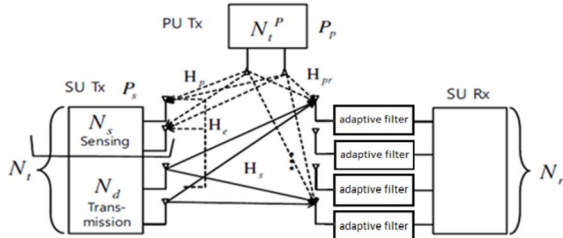

Fig 3. System model for tranSensing with minimum interference

The adaptive filter is the system with a linear filter that has a transfer function controlled by variable parameters and a means to adjust those parameters according to an optimization algorithm. The structure of the adaptive filter is shown in Fig 4.
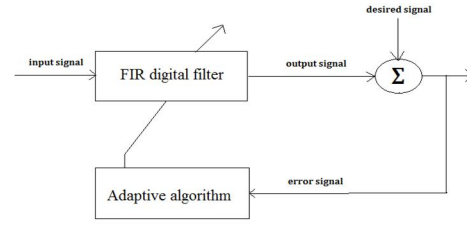

Fig 4.Structure of adaptive filter

The signal received by the secondary user receiving antennas will be passed through the adaptive filter. The adaptive filter consists of a linear filter in which the signal received will be filtered. The filtered output signal will be then compared with the desired signal and their difference is considered as the error signal. Then the adaptive algorithm will be performed in this error signal and the filter coefficients will be updated each time till the error is minimized to the maximum.

IV IMPLEMENTATION

Ideally, joint optimization should be performed for every instantaneous channel state for all possible sets; however, this constitutes quite a burden for the SU. In order to reduce the computational complexity, we propose a two-stage algorithm which consists of correlation-based antenna partitioning (CAP) and conditional sensing duration control (cSDC) using channel statistics and antenna correlation. In particular, we propose a min-max distance based-search method for the exponential correlation matrix case. In the proposed two-stage algorithm, correlation-based antenna partitioning is performed before cSDC.

1)Correlation-based Antenna Partitioning, CAP: From the upper bound expressions of ergodic correlated MIMO capacity, we can clearly distinguish the channel-correlation effect on the capacity for a given SNRs. We can then proceed with antenna selection based on the correlation channel matrix $\det(R_{Stt})$.

$$\det \begin{matrix} 1, 2, 3, \dots \\ 1, 2, 3, \dots \end{matrix} = {}^{\{ \ , \ \}} \qquad (1 - \ )$$

Note that the selected antenna subset does not change unless the channel characteristic, e.g. SNRs and SNRp, changes. This is because $\overline{\ }_{s,T}$ is evaluated based on channel statistics, not instantaneous channel values in $T_{s,T}$. In

addition, the computational complexity also decreases because the CAP compute the $\det(R_{Stt})$ instead of Cs.

2)Conditional Sensing Duration Control (cSDC): The optimal number of sensing antennas Ns decreases as SNRp increases. Specifically, where SNRp >-2dB, the SU capacity increase with $N_s^* = 1$ as M_s^* decreases. If the sensing requirement is sufficiently satisfied with smaller samples Ms than M, we do not need to sense the PU signal for M −Ms samples. This means we can then use Ns sensing antennas to transmit data signals for M –Ms sample.the conditional sensing duration control algorithm proceed as follows.

1. If $N_s^*=1(N_d^*=N_t-1)$ through CAP, compute average secondary user capacity, $\overline{}^*_{s,T}$,for $1\le M_s\le M$.

2. Select M_s^* s.t.arg $\max$ $_,$ $_,$.

Conditional sensing duration control is used when the optimal number of sensing antennas is1. In this case N_t-1 antennas are used for transmission during M_s samples. After M_s samples, all N_t antennas are used for data transmission with M-M_s samples.

$$\overline{}^*_, = 1 - (_,1,^*) \underline{\overline{}}^* (-1,)$$
$$+ \frac{-^*}{} (,)$$
$$+ (1-)(1-)$$
$$*\underline{\overline{}}^* (-1,)$$
$$+\frac{-^*}{} (,)$$

3)Adaptive algorithm:An adaptive algorithm is used to estimate a time varying signal by adjusting the filter coefficients so as to minimize the error.There are many adaptive algorithms like RecursiveLeast Square (RLS), Kalman filter,but the most commonly used is the Least Mean Square (LMS) algorithm.

LMS algorithm: This algorithmestimates the solution to the Weiner-Hopf equations using gradient descent methodwhich finds minima by estimating the gradient.

$$h () = h () + \nabla \{()\}$$

The filtering operation is performed with theprevious version of the coefficients.

$$y(n)=\Sigma h () (-)$$

The computed output is compared with the expected output.

$$e(n)=d(n)-y(n)$$

The coefficients are updated using the following computation.

$$h_k(n)=h_k(n-1) + \beta^* e(n) (-)$$

V . RESULT AND CONCLUSION

Fig 5 shows the signal to noise ratio vs the secondary user's capacity (bits/sec/Hz) for the transensing approach. We can seethat when the signal to noise ratio increases, the secondary user's capacity also increases. Fig 6 shows the number of secondary users vs ratio of active secondary users for R=0.1, 0.3, 0.5. We can see that initially the secondary users perform only sensing and after detecting the presence of white spaces, the secondary users start performing both the sensing and transmission simultaneously.
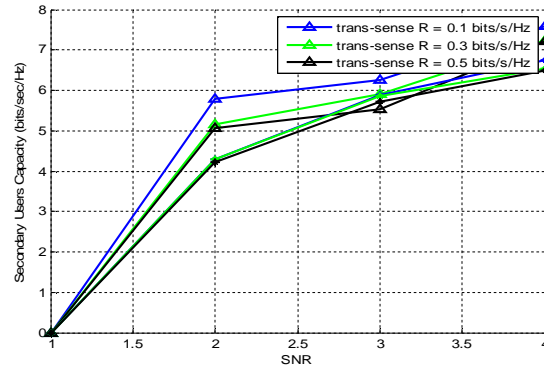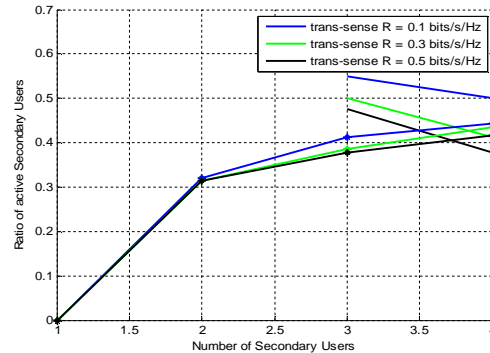

Fig 5.SNR vs SU capacity

Fig 6Number of SU vs Ratio of active SU

Fig 7 shows the correlation coefficient vs average secondary user capacity for the R=0.1,0.3,0.5. We can see that the correlation coefficient value becomes more similar for R=0.1, 0.3, 0.5 as the average secondary user capacity decreases leading residual interference.Finally the interference occurring in the transensing approach will be reduced by using the adaptive filter.
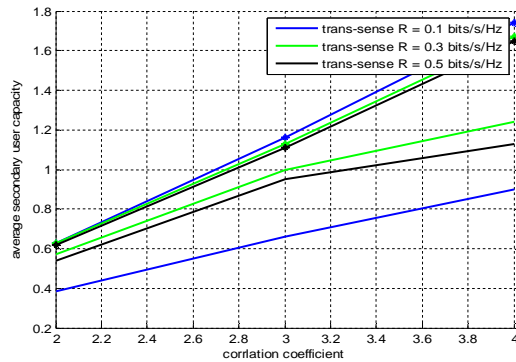
Fig 7. Correlation coefficient vs Avg SU capacity

Finally the interference occurring in the transensing approach will be reduced by using the adaptive filter.

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