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Silence Reporting for Cooperative Sensing in Cognitive Radio Networks

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Abstract

A cooperative spectrum sensing has been proposed to improve the sensing performance in cognitive radio (CR) network. However, cooperative sensing causes additional overhead for reporting the result of local sensing to the fusion center. In this paper, we propose a technique to reduce the overhead of data transmission of cooperative sensing for applying the quantum data fusion technique in cognitive radio networks by omitting the lowest quantized in the local sensed results. If a CR node senses the lowest quantized level, it will not send its local sensing data in the corresponding sensing period. The fusion center can implcitly know that a spectific CR node sensed lowest level if there is no report from that CR node. The goal of proposed sensing policy is to reduce the overhead of quantized data fusion scheme for cooperative sensing. Also, our scheme can be adapted to all quantized data fusion schemes because it only deal with the form of the quantized data report. The experimental results show that the proposed scheme improves performance in terms of reporting overhead.

Keywords: *Cognitive radio, cooperative sensing, spectrum sensing, quantized data fusion*

1. Introduction

Cognitive radio (CR) allows secondary users (SUs) to opportunistically access a licensed band when the primary user (PU) is absent. The concept of CR has been proposed as a mechanism to efficiently utilize spectrum holes by exploiting its availability by cognitive users (i.e., SU) [1]. The ability of finding spectrum opportunities is called spectrum sensing, which is considered one of the most critical components in a CR system. Spectrum sensing allows SUs to find these spectrum opportunities. In order to improve the sensing performance, cooperative spectrum sensing has been proposed. In cooperative sensing, nodes transmit sensed results to the fusion center to determine whether there is a primary user or not in the target spectrum [2].

However, cooperative sensing causes additional overhead for reporting the result of local sensing to the fusion center. Considering the wideband environment, bandwidth usage caused by sensing overhead increases, thus giving rise to serious implementation problems.

Data fusion techniques for cooperative sensing can be classified into three types according to the fusion method. In hard decision fusion, each recognized CR node transmits its decision on the existence of a PU to

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the fusion center [3]. Since only one bit is required per sub-band, the overhead is small but the sensing performance is relatively low. In soft data fusion, the sensed result is directly transmitted to the fusion center without making a decision on the channel state [4-6]. Since the fusion center makes decisions based on more detailed information, the sensing performance of soft data fusion is better than hard decision fusion, but the overhead for sensed data transmission increases. The quantized data fusion technique is a compromise method for the above two techniques [7-11]. This technique has a better detection performance than hard decision fusion and has less overhead than soft data fusion.

In this study, we propose a cooperative sensing scheme to reduce the overhead of reporting the result of local sensing by omitting the lowest quantized level in the local results. The main contributions of this paper are summarized as follows:

- We reduce the overhead of quantized data fusion scheme for cooperative sensing, which is evaluated through our simulation.
- Our scheme can be adapted to all quantized data fusion schemes because it only deal with the form of the quantized data report.

The rest of paper is organized as follow: Section 2 introduces our system model. Section 3 covers the proposed data fusion scheme to reduce the size of reporting results and derives bandwidth cost. In section 4, we evaluate the proposed scheme with different scenarios. Finally, section 5 concludes this paper.

2. System model

In this paper, we assume that CR nodes in the network conduct cooperative sensing to achieve improved performance for spectrum sensing in a CR network. In the process of cooperative sensing, a fusion center first selects a target band which is supposed to be idle. The fusion center requests cooperative sensing for the target band to the SUs in the network. Each CR node performs local sensing to learn the status of the target spectrum. Each SU uses a technique such as energy detection to reduce the overhead of cooperative sensing. After obtaining the result of local sensing, Each CR node sends it using one of the quantized levels to the fusion center. The total number of quantized levels is 2^B when B is the number of bits required to represent the sensing data of one sub-band. Finally, the fusion center makes a global decision about existence of a PU in the target bands using the reported results from CR nodes.

We apply the multi-bit quantization for our data fusion scheme as proposed in [7]. The advantages of this quantization scheme are using a simple algorithm to quantize data and provide a parameter-determining method without numerical search that has been required in the suboptimal linear-quantization multi-bit combining (SLMC) scheme [8]. We assume that there are two types of period in the cooperative sensing; the sensing period and the transmission period. In the sensing period, CR nodes try to find out available spectrum whole using cooperative sensing. After the sensing period, CR nodes transmits the status on the detected idle spectrum during the transmission period. Figure 1 illustrates an example of cooperative sensing periods that consist of sensing and transmission periods.

Figure 1. Cooperative sensing period

3. Silence reporting for cooperative sensing

To reduce the overhead caused by local sensing report in the cooperative sensing, we propose a cooperation scheme called silent reporting that allows a node to skip the local sensing report when its local sensed result is the lowest quantized level. The main idea of our proposed scheme is that a fusion center infers whether a node sensed the lowest level based on presence of the report from each node. In the proposed scheme, a CR node performs spectrum sensing using energy detection and transforms the result to a quantized level. If its sensed energy level is the lowest quantized level, a CR node stays idle until the end of the sensing period.

We introduce a new period called a reporting period when CR nodes are only allowed to report the local sensed result within this period. The reporting period should be shorter than the sensing period and is included in the sensing period. The rest of time in the sensing period except the reporting period should be enough to fuse the sensed results cooperatively and make a decision of PU's existence in the target band.

The fusion center waits for the report of local sensing from CR nodes until the reporting period is expired. After the reporting period is finished, the fusion center finds out those CR nodes that have no report. If the fusion center did not receive any data from a CR node within the reporting period, the fusion center indirectly knows that the CR node sensed the lowest energy level at the assigned sub-band. After that, the fusion center assigns its results as the lowest quantized level. An assumption behind this scheme is that the report of CR nodes must arrive within the sensing period if CR nodes sensed some energy levels above the lowest level. Thus, the fusion center can reconstruct the statistics of local sensing even though some CR nodes do not transmit any result of local sensing. If CR nodes have similar spectrum condition and most CR nodes sense the lowest level, the performance of our proposed scheme will be maximized. Also, smaller B has more probability that sensing result is the lowest level because if B is small, the number of quantized levels is also small and it leads more energy levels are marked as the lowest level.

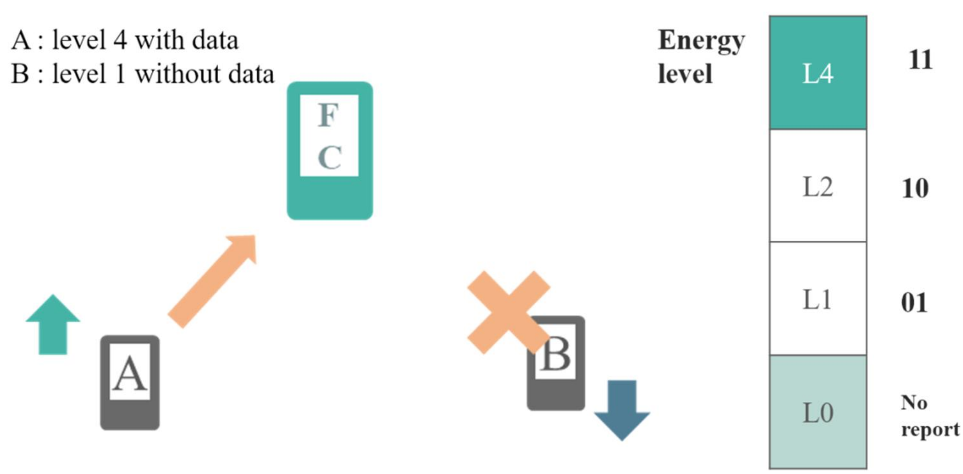

Figure 2. An example of the proposed scheme (B=2)

Figure 2 shows an example of the proposed scheme when B is two. The number of quantized energy levels is four and assigns two bits to each energy level except the lowest level, L0. Node A has sensed level 4. Thus it sends its quantized data to fusion center. On the other hand, the local sensing data of node B is level 1. Node B skips the report of local sensing to the fusion center in the sensing period. After the sensing period expired, the fusion center knows that node B has sensed the lowest level because there is no report from B.

4. Simulation

In this section, we evaluate the performance of the proposed data fusion scheme. For simulation, we implemented four fusion schemes, hard decision fusion, soft data fusion (SLC, Square Law Combining) [5], an existing quantized scheme [7], and the proposed scheme, using MATLAB. We considered 10 SUs with a single PU in a CR network. Also we set parameters such that the number of samples is 1000 and the SNR is -15dB for all SUs. Nodes were randomly deployed in a 500m x 500m square area.

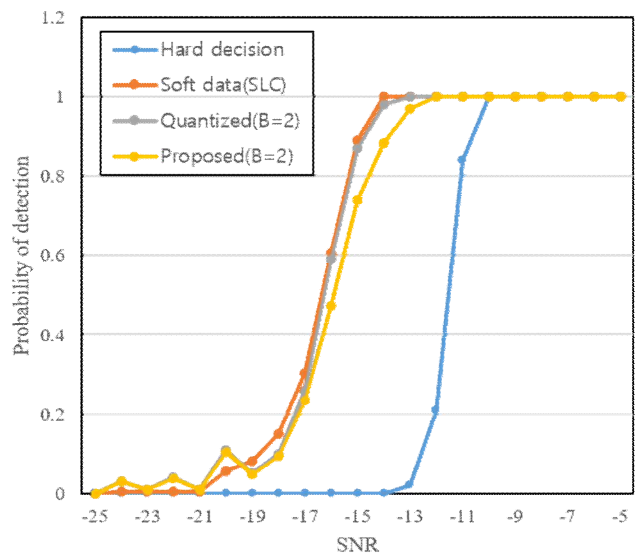

Figure 3. SNR vs probability of detection

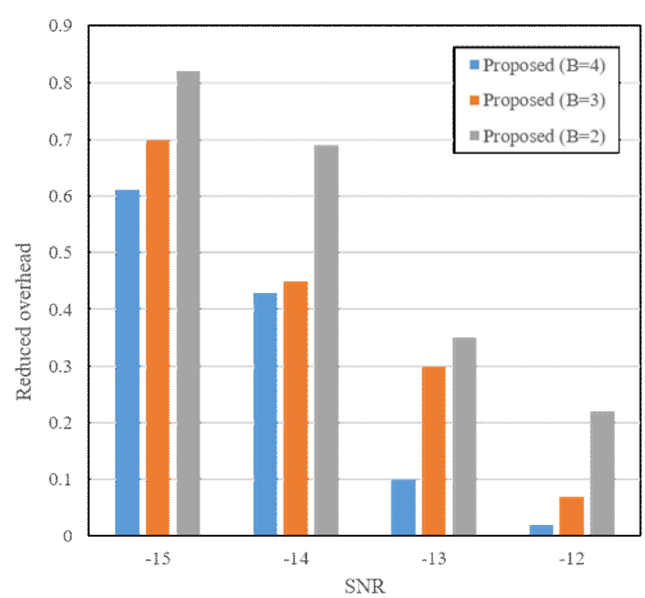

Figure 4. SNR vs reduced overhead

Figure 3 shows the detection performance of the four fusion algorithms. It is shown that the performance of the proposed scheme is slightly degraded compared to normal quantized data fusion. The reason of this degradation is miss detection caused by delay, which happens when a fusion center could not receive the report in the right time due to delay even though the CR node senses a higher quantized level.

Figure 4 shows the average reduced overhead compared with normal quantized data fusion scheme as a function of the SNR under various numbers of quantization bits, B. We can see that reduced overhead decreases by increasing the SNR because the increase of the SNR leads to the decrease of the chance to sense the lowest quantized level in the local sensing. Moreover, it can be inferred from the figure 3 that decreasing B also impacts on the amount of reduced overhead. The reason is that if B is small, there is a higher probability that the lowest level appears in the local sensing.

5. Conclusion

In this paper, we propose a technique to reduce the overhead of reporting the result of cooperative sensing by applying the quantum data fusion technique for cognitive radio by omitting the report of the lowest quantized level in the local sensing. If a CR node senses the lowest quantized level, it will not report its local sensing data in the sensing period. The fusion center can implicitly know that a specific CR node sensed the lowest level if there is no report from that CR node. The simulation results show that the proposed scheme reduces the overhead of reporting the result of cooperative sensing.

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