Notification Protocol of Sensing Information in Cognitive Radio System

Hyoungsuk Jeon, Sunghun Kim, Joongsoo Ma, and Hyuckjae Lee
School of Engineering, Information and Communications University
119 Munjiro, Yuseong-gu Daejeon, 305-714, Korea
E-mail: {hschun, wanhuns, jsma, hjlee}@icu.ac.kr

Abstract

In recent years, the cognitive radio (CR) has been receiving a great attention to overcome spectrum scarcity. Up to now, many authors have proposed CR core technologies such as protocols, spectrum sharing method and sensing techniques. In this paper, we focus on notification protocol to exchange sensing information in the network. Since every node in CR network should send its sensing results to the gathering center, it takes long time to complete the notification process. So, in this paper, we design new notification protocol to minimize the number of notifications. It operates dynamically in accordance with prior informed reporting data. We demonstrate its superiority by Monte Carlo simulation.

Keywords: cognitive radio, spectrum sensing, notification, protocol

1. Introduction

In most countries, the radio spectrum has been managed by traditional command and control, which gives an exclusive right to radio access technology (RAT) to access predefined band. Such model controls the mutual interferences among RATs easily, but, it creates a fundamental cause to drop the spectral efficiency of the radio spectrum in time and space by granting RAT a right to access exclusively. Also, regardless of any country, the largest and most worthy part of the radio spectrum is already assigned to existing services. Due to this monotonous management model and the lack of radio spectrum, regulators have been facing difficulties to assign the radio spectrum for next generation wireless communication systems which require the wideband spectrum. Therefore, we should consider making efficient use of radio spectrums, where the demand exceeds the supply.

Recently, the cognitive radio (CR) has been receiving a great attention to overcome this problem [2]. The CR has its roots in software defined radio (SDR) and senses outside environments, learns from the environments, and based on these analyses, enables the most suitable transmission under given resources [3]. Thus, we expect this smart technology to give a chance to a certain band shared by several systems, and solve the radio spectrum scarcity.

In CR, every process starts with the result of spectrum sensing that is aware of the environments and is informed of vacant bands [3]. Up to now, many precise spectrum sensing techniques have been developed for signal identification in this field. On the other hand, the development of control mechanism to manage the sensing information is in slow progress. In this context, we propose the adaptive protocol to exchange sensing information efficiently when CR users collaborate with each other. The proposed protocol operates dynamically in accordance with prior informed notifications. We demonstrate its superiority by Monte Carlo simulation.

This paper is organized as follows. In section 2, we briefly overview the cooperative sensing. In section 3, we propose sensing notification protocol for a centralized CR network and its functional features. Section 4 deals with the performance analysis. Finally, section V concludes this paper.

2. Cooperative sensing and related works

In sensing period, every node in CR network stops the data transmission to detect licensed users (LUs) and, based on the result, it decides the presence of LUs. The main problem in spectrum sensing is the degradation of detection performance when a CR node is exposed to fading from both shadowing and multi-path. In this case, even precision detector can not help missing LUs. This motivates the development of cooperative sensing. For example, in case of one CR user not perceiving LU due to the shadowing, collaboration with other CR users helps improve the detection probability of blind CR user. In [4], authors analyzed potential benefits of cooperative sensing.

To put out the maximum cooperation gain, accompanied by an accurate detector, CR network needs efficient mechanisms to control sensing information and reduce medium access control (MAC) overhead. In [5], Data fussing algorithm has been proposed. It makes the sensing data reporting time minimize by using physical layer signaling. By contrast, other researchers designed the notification protocol which has a root in MAC layer packet and proposed

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a cluster-based opportunistic spectrum access network (OSAN) architecture [6]. It is consist of several clusters and they help each other to access licensed spectrum opportunistically. Its TDMA-based notification protocol is shown as figure 1. Each cluster has several (just denote *N*) associated nodes and the cluster head. In notification period, every node transmits sensing results to cluster head sequentially and then the cluster head determines whether LU is present or not.

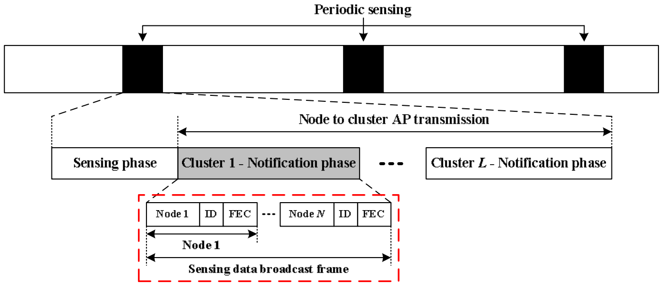

Figure 1. Spectrum sensing protocol in [6]

The common point what these papers consider is that the access point (AP) should receive sensing information of all CR users without exception, because some may contain valuable information which others do not have. As a result, the length of protocol depends on the number of CR node in a network. On the one hand, this can prevent possible information loss in LU detection, but on the other hand, what all nodes report sensing information to AP may make cooperative process longer unnecessarily. For example, if some CR nodes detect same LUs, the AP should superfluously receive a large number of overlapped sensing results. Hence, in this paper, we would propose efficient protocol that can solve the above problems.

3. Adaptive protocol for cooperative sensing

The fame structure of our protocol which is depicted in figure 2 mainly consists of two phases which are the sensing phase and the notification phase.

We assume the centralized cooperative scenario. Therefore, there is a controlling AP that connects CR nodes. CR nodes transmits a packet to the AP through the predefined dedicated channel, and we assume that the AP gathers sensing information (there are *M* radio channels to be sensed) of all nodes (there are *N* nodes in a CR network) and it is performed using synchronized TDMA on a single dedicated channel which is not affected by any LU. Our proposed algorithm regularly broadcasts suppression message to make avoid overlapped information before nodes notify their sensing information to the AP and this leads dynamic operation without relying on the number of nodes. Herein, we go into details about the proposed protocol.

3.1. Sensing phase

The spectrum sensing is the technique that determines where spectrum is occupied by LUs and is one of the most important techniques in CR system. In the sensing phase, CR nodes perform the spectrum sensing. Every node stops its transmission to eavesdrop only on LU communications. The detection performance of LU depends on sensing duration. The longer observation time, the better detection performance. Also, it depends on the type of detectors. Energy detector, feature detector and its combination are possible candidates in CR system [7]. However, since sensing topics are beyond our work, limiting detector issues, we only consider how to handle the sensing results from ideal detector.

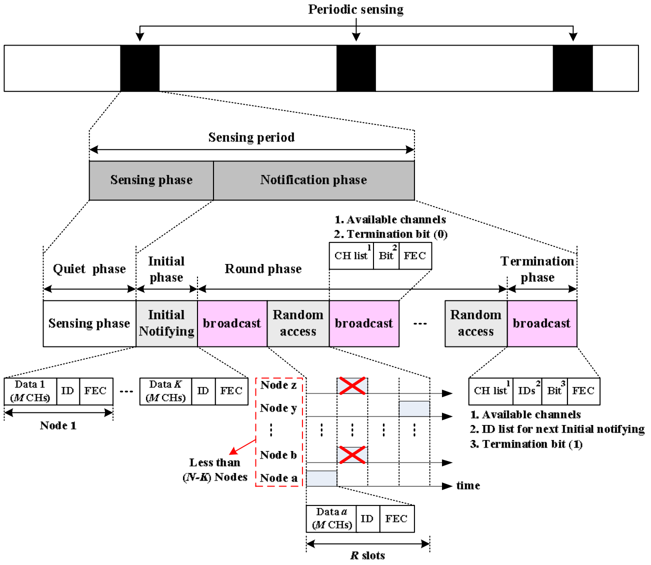

Figure 2. Frame structure of proposed protocol

3.2. Notification phase

After sensing phase, each node transmits sensing results to AP in notification phase. The results can be a series of hard (vacant or occupied) decision or soft (multi-level) decision. Our notification phase can be divided into three parts. One is initial phase, another is round phase and the other is termination phase. Each phase is composed of fixed-size time minislots.

3.2.1. Initial phase. Predefined *K* nodes transmit sensing results to AP one by one in this phase. If AP has the ability to detect LUs in sensing phase, this phase can be omitted or shortened. Otherwise, it is necessary to start the first broadcast execution of round phase. Each node transmits its sensing result and node ID to the AP with forward error correction (FEC). Participants of initial phase may be changed in every sensing period by broadcast packet of termination phase.

3.2.2. Round phase. Round phase repeats broadcast and random access. In broadcast period, combining notifications of CR nodes (we consider OR operation), the AP informs channel state to all nodes. If there are remaining nodes which have LU information not containing in a previous broadcast packet, they try to access the AP with uniform random numbers in random access period of round phase. At this time, access nodes transmit their channel information and node IDs. Again, the AP gathers this information and broadcasts the updated channel state to nodes. The round phase repeats until there is no contender in random access phase.

3.2.3. Termination phase. Lastly, after the round phase, the AP transmits a packet including three kinds of information unlike broadcast of round phase. First of all is the final channel state having results from nodes reporting. Secondly, it announces node ID list for initial notifying phase of next sensing period. This is important to relocate initial notifying node order in the next sensing period. It is performed by analyzing each nodes' sensing details delivered so far. The node that finds the most LUs has the highest priority. By correlating channel state data with this node, AP reorders the notification sequence in ascending order (The lower correlation, the higher priority). This appears to be effective by selecting nodes in different circumstance automatically, minimizing the length of round phase and eventually leads to activate dynamic. Finally, termination bit would be sent to alarm the completion of sensing period.

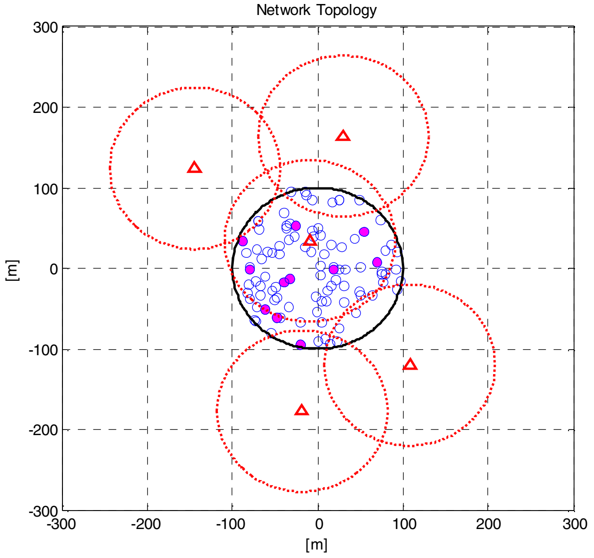

Figure 3. An example of the node position and network topology; circles - CR nodes, colored circles - initial notifying CR nodes, triangles - LU, black solid line - CR network service coverage, red dotted lines - LU service coverage

4. Performance results

We assume the length of every packet in notification phase of section 2 is same and all packets are exchanged perfectly except the collision of random access. Figure 3 shows network topology in our simulation. The service ranges of both CR nodes and LUs are the radius of 100 meter. The positions of LUs are randomized in the 300 [m] by 300[m] square area.

The performance of proposed protocol depends on the number of initial notifying nodes(K), LUs(L), radio channels(M), CR nodes(N), and random access slots(R). Firstly, we simply set L and M to 5 and 10 respectively and try to find the most suitable parameters of K and R for various N by Monte Carlo simulations. Figure 4 shows the number of average required packets during a sensing period for N=50. The peak point for small K and R becomes stronger as N is increased because small K causes the large number of nodes to access in round phase and this leads vast packet collisions for small R.

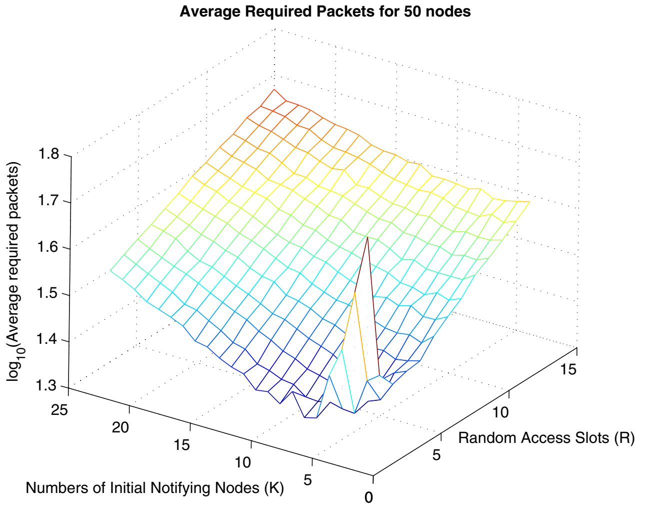

Figure 4. The number of average required packets for 50 CR nodes. We assume that the length of all packets in a sensing period is same.

Figure 5 compares the number of average required packets of proposed protocol with that of conventional one in [6] that all CR nodes notify the sensing information to the AP sequentially. As shown in figures 5, required packets of proposed protocol are not directly proportional to the number of CR nodes.

Finally, we simulate proposed protocol for several sensing periods. We expect reordering process of initial notifying node in termination phase is effective as sensing period goes by. In simulation, we set LU's state (occupied channel, position) to change every 5 sensing periods. The results are in figure 6. As our expectation, we can observe that average required packets keep on minimum level between changes of

LU state. Furthermore, the slope of peaks is also decreased as time goes by. This is reason why positions of initial notifying node are separated due to reassigning of reporting order.

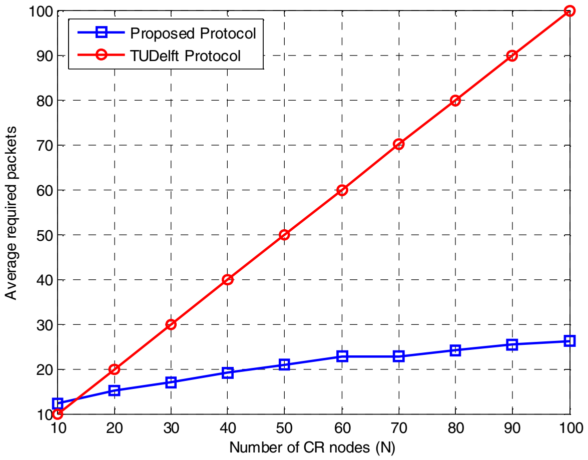

Figure 5. Comparison of the number of average required packets for various numbers of CR nodes

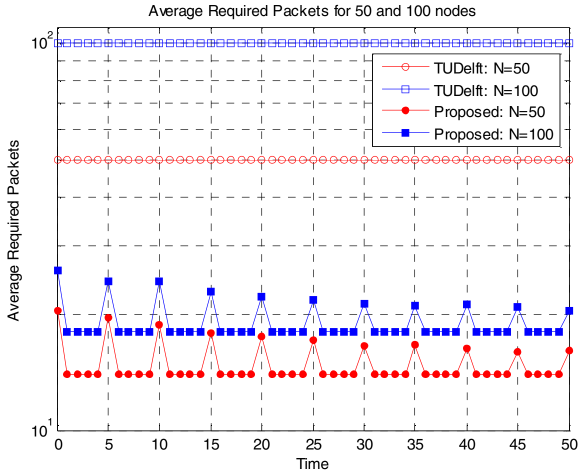

Figure 6. Average required packets

5. Conclusions

As the wireless communication services grow quickly, the seriousness of spectrum scarcity has been on the rise gradually. The CR, an emerging technology, has been come out to solve today's spectrum scarcity. In this paper, we focus on spectrum sensing part, the most critical part in CR, and propose the notification protocol to exchange sensing information efficiently.

The noticeable feature that discriminates our protocol from others is that it is designed to avoid overlapped information by inserting broadcast periods. Hence, it makes possible to dynamically coordinate sensing period in CR network. Simulation results show that the proposed protocol operates efficiently in the large network and static channel condition. Optimization of required initial notifying nodes as well as random access slots will be solved in the future.

6. Acknowledgement

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7. References

[1] K. Hooli, *et al.*, IST-2003-507581 WINNER, "D6.3 WINNER Spectrum Aspects: Assessment Report", IST WINNER, Dec. 2005. [Online]. Available: http://www.ist-winner.org

[2] Federal Communications Commission, "Unlicensed Operation in the TV Broadcast Bands", ET Docket No. 04-186, 2004.

[3] J. Mitola, "Cognitive Radio: An integrated agent architecture for software defined radio", Doctor of Technology, Royal Inst. Techno. (KTH), Stockholm, Sweden, 2000.

[4] A. Ghasemi, and E.S. Sousa, "Collaborative Spectrum Sensing for Opportunistic Access in Fading Environments", *2005 1st IEEE international Symposium on New Frontiers in Dynamic Spectrum Access Networks (DySPAN 2005)*, Nov. 2005.

[5] T. Weiss and F.K. Jondral, "Spectrum Pooling: An Innovative Strategy for the enhancement of Spectrum Efficiency", *IEEE Communications Magazine*, Vol. 42, pp. S8-S14, Mar. 2004.

[6] P. Pawelczak, C. Guo, R. Venkatesha Prasad and R. Hekmat, "Cluster-Based Spectrum Sensing Architecture for Opportunistic Spectrum Access Networks" IRCTR-S-004-07 Report, 12 Feb. 2007.
[Online].Available:
http://dutetvg.et.tudelft.nl/~przemyslawp/files/osa_arch.pdf

[7] D. Cabric, S. Mishra, and R. Brodersen "Implementation issues in spectrum sensing for cognitive radios", in *Conference Record of the 38th Asilomar Conference Signals, Systems, and Computers*, pp. 772-776, 2004.