Independent Spectrum Sensing in Cognitive Radio Networks

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Abstract

The spectrum sensing and channel access is a classic exploration vs. exploitation problem for cognitive radio overlay networks, where the secondary users access the idle portion of licensed primary users. We propose a simple architecture to separate the spectrum sensing form the channel access so that optimal sensing can be achieved.

1. Introduction

The Dynamic Spectrum Access (DSA) has been proposed as an alternative to solve the problem of increased data communication and congested spectrums especially in 2.4 GHz Industrial, Scientific and Medical (*ISM*) radio bands. ISM radio band is mainly used by Wi-Fi or Wireless Local Area Network (WLAN) (IEEE 802.11 Standard). This phenomenon can said to be the result of the so called mobile smart devices such as smart phones, tablets and notebooks. Cognitive Radio (CR) was introduced as a DSA system [1][2].which can solve the overcrowding problem by dynamically accessing the under-used spectrums such as TV white space (TVWS).

Research for CR in TVWS for broadband usage has been conducted for more than a decade and there is an existing standard already. The Regional Area Network (RAN) (IEEE 802.22 Standard) [3]. RAN focuses on broadband access network for rural areas. Their architecture is centralized with base stations controlling the air interface of fixed broadband devices. At present, there is no existing device which uses this RAN standard. The Dynamic Spectrum Access (DSA) for the most widely used wireless technology, WLAN or Wi-Fi is currently still under development in IEEE 802.11af task group.

The basic CR architecture has two types of users; Primary Users (PUs) to whom the channel is licensed by the authorities and unlicensed Secondary Users (SUs). SUs can access the channel when the channel is idle without interfering the Primary Users (PUs). There are two types of access methods: CR underlay access in which SUs employ power control to mitigate interference to PUs and CR overlay access in which power control not used.

Since there is no power control in CR overlay access, the SUs cannot coexist in the same channel with the PUs at the same time. In other words, if a PU appears on a channel, the SUs on that channel must stop transmitting. Then the SUs can switch to another channel to continue their communication. This is known as spectrum handoff. This CR overlay access fits the IEEE 802.11 Standard because IEEE 802.11 employs TDMA for multiple access which reflects the data communication of the Internet.

There are two types of spectrum handoffs; reactive and proactive spectrum handoff. In reactive spectrum handoff, SUs perform spectrum handoff only when they detect a PU signal. On the other hand, proactive spectrum handoff estimates the arrival of PU signal and performs spectrum handoff before it arrives. There is always some interference in reactive spectrum handoff because spectrum handoff is carried out only when PU signal is detected. There is no such issue in proactive handoff but since PU signal arrival is estimated, there must be an acceptable error bound.

Whether reactive or proactive spectrum handoff is implemented, the spectrum sensing and channel access is a classic exploration vs. exploitation problem for CR overlay access. Spectrum sensing is an integral part of CR to detect PU signals. But Federal Communications Commission (FCC) ruled spectrum sensing requirement as optional and authorize an access scheme with a geo-location database of TVWS [4]. However, FCC didn't mention how the database should be built. Based on the FCC scheme, we propose a simple architecture to separate the spectrum sensing form the channel access so that optimal sensing can be achieved.

2. Network Model

We will consider the conventional WLAN architecture for our proposal. There is an Access Point (AP) or wireless router acting as a gateway which is connected to the backbone network. There are N_2 number of SUs which the AP is serving as shown in Fig (1). The SU devices can be any wireless device with a Wi-Fi interface. A pair of PUs is included to reflect licensed PU activity. The network coordination between SUs is achieved by Distributed Coordinated Function (DCF).

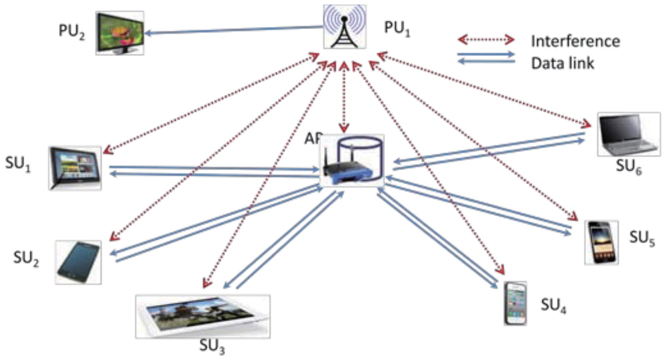

Figure 1. Wireless LAN in CR environment

3. Spectrum Sensing

We assumed that each SU has a single channel spectrum sensor and energy detection at physical (PHY) layer is used for spectrum sensing. We can draw hypothesis of either idle channel state, H_0 or busy channel state H_1 in discrete time as:

$$H_0\colon y(\tau) = u(\tau) \quad \text{(OR)} \quad H_1\colon y(\tau) = x(\tau) + u(\tau) \qquad (1)$$

where $u(\tau)$ is complex-valued independent and identically distributed (i.i.d) Gaussian with zero mean and variance σ_u^2; $x(\tau)$ is the PU signal and $y(\tau)$ is the received signal at SU spectrum sensor. $x(\tau)$ is also assumed to be i.i.d complex Gaussian with zero mean and variance σ_x^2. The testing using optimal energy detector with sufficient statistic is:

$$E(y) = \frac{1}{N_s}\sum_{\tau}^{N_s} \left|y(\tau)\right|^2 \underset{H_0}{\overset{H_1}{\gtrless}} \varepsilon \qquad (2)$$

where ε is the decision threshold and N_s is the total number of samples.

4. Sensing Policy

In conventional sensing policies for CR, quiet periods in which there is no SU transmission are scheduled to detect the PU signal. In our proposal, we assumed that one SU can sense one channel while another SU transmit in another channel. This assumption is valid since every logical channel is separated by guard bands to mitigate interference from neighboring channels. Our proposed sensing policy is depicted in Fig (2). The network is operating on CH1, for example, SU1 is downloading data from AP. As it is usual case in DCF, all other SUs which overheard the RTS/CTS exchange will update their Network Allocation Vector (NAV). But during the NAV countdown, instead of going to sleep, the idle SUs will sense different channels in allocated time.

The SUs will continue to sense and store the PU activity information, namely BUSY or IDLE, over a period of time. The SUs will send their sensed information to AP at the end of each beacon interval. AP has the default IEEE 802.11 beacon interval which is 100 time units (TU). (1 TU = 1024 microseconds). So, the SUs will update the PU activity on every beacon interval which will be maintained in the database stored in the AP.

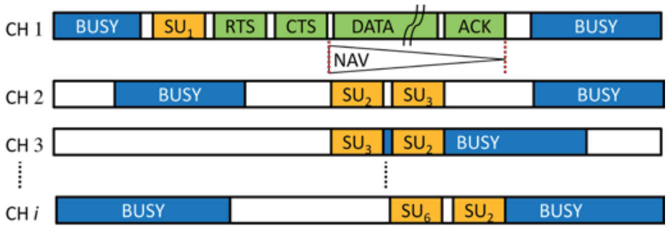

Figure 2. Independent sensing policy

5. Conclusion

In this paper, we propose an independent spectrum sensing policy for cognitive radio overlay access networks. The database is stored in the Access Point. We propose a novel sensing policy to detect the Primary User activity.

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REFERENCES

[1] J. Mitola, “Cognitive radio: An integrated agent architecture for software defined radio,” Doctor of Technology, Royal Inst. Technol. (KTH), Stockholm, Sweden, 2000.
[2] Simon Haykin, ”Cognitive Radio: Brain-Empowered Wireless Communications”, in IEEE Journal on Selected Areas in Communications, Vol. 23, No. 2, pp 201-220, February 2005.
[3] IEEE Standard 802.22TM – 2011.
[4] Federal Communications Commission, “FCC FREES UP VACANT TV AIRWAVES FOR “SUPER WI-FI” TECHNOLOGIES”, Rep. ET Docket Nos. 03-280 and 04-186, September 2010.