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Dynamic Spectrum Access in Cognitive Radio Networks Using USRP and LabView

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Abstract- In cognitive radio network, dynamic spectrum access is considered as the base which allows unlicensed secondary user (SUs) to access licensed spectrum allotted to licensed primary users (PUs). SUs identify the idle band and access them without interfering in primary users (PUs). For peer-to-peer based communication in dynamic in dynamic spectrum access. SU transmitter and SU receiver should use same channel to communicate. In case of jamming attacks and wideband regime fixed common control channel are not viable. In this paper, we will discuss a test bed using Universal Software Radio Peripheral (NI USRP) devices and we will use LabView and MATLAB as scripting extension to program NI USRP devices. When SU transmitter and SU receiver identify idle channels, they use best channels, they use best channel to communicate. We can use sequential channel scanning and quorum based rendezvous methods without using control channels. Test bed setup is organized to make these schemes.

Index terms—Dynamic spectrum access, cognitive radio network, spectrum sensing, frequency hopping, Universal software radio peripherals (USRPs).

I. INTRODUCTION

Growing technology has initiated many electronic devices to establish a link with the Internet. Exponentially growing wireless networking technology has allowed the electronic devices to connect to internet which in past was not possible, now many devices are able to link and share the gigantic amount of information using wireless technology. Due to increase i n number of devices and users there is an enormous increase in wireless traffic thus wireless service providers experience scarcity in spectrum. Ac cor di ng to recent studies it is pr ove d that this scarcity is observed due to static spectrum allocation policy. [2]

In cognitive radio networks (CRN), Dynamic spectrum access (DSA) is solution for this spectrum scarcity which arises due to static spectrum allocation policy. In CRN, rather than depending on allotted spectrum defi ne d in traditional wireless networks, we use cognitive radio w h i c h taps into the resources of licensed primary users to share with the unlicensed secondary users. Smart radio devices can connect to the internet through Internet of everything (IoT). [3]

In CRN, DSA i s i m pl e m e nt e d s uc h t hat SUs s h o u l d n o t create any harmful interference to PUs. In order to communicate with their intended receivers SUs scan the channel and finds the idle bands and uses these idle bands. If transmitter and its receiver are situated in two different locations and want to communicate with each other, they need to find idle channels. After that a communication link is established using common control channel in a suitable channel. However, using common control channel is not achievable in wideband regime for DSA in CRN. Also use of common control channel is sensitive to jamming attacks. Therefore to establish a communications link using rendezvous methods, SU transmitter and receiver pair needs to establish a flying link. In this paper, we present a small scale test bed for rendezvous for SUs using the National Instruments USRP for peer-to-peer based communication using DSA in CRN. We can program USRP devices using LabView and MATLAB scripting extensions to tune transmit parameters such as transmit power, channels, sample rate, etc. We assume that the USRPs (i.e., SUs) have idle channel information. In order to communicate with each other in cognitive radio ad hoc networks they need to find the common channel among idle ones.

The rest of the paper is organized as follows: In Section II, we present a design of a testbed. Section III presents different schemes for finding common channels for SUs to communicate with each other followed by the conclusions in Section IV.

II. A TESTBED DESIGN AND SYSTEM MODEL

We used NI USRP 292l, Laptop computers with LabView and MATLAB software to design a testbed as shown in Fig. l. Each laptop controls the USRP device to tune transmit and

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receive parameters. The transmitter laptop computer (left) in Fig. l is configured with an IP address (l92.l68.l0.l0) and the receiver laptop (right) is configured with an IP address (l92.l68.l0.ll) with same subnet mask

(255.255.255.0) to put them in the same subnet. The USRP devices connected to laptops are configured with separate IP addresses l92.l68.l0.2 (transmitter) and l92.l68.l0.3 (receiver). USRP devices have the following specification and calibration data as shown in Tables l and 2. [1]

Frequency range	2.4 to 2.5 GHz; 4.9 to 5.9 GHz
Frequency step	< l KHz
Maximum output power	2.4 - 2.5 GHz: 50 mW to l00 mW
	4.9 - 5.9 GHz: 50 mW to l00
Gain range	0 dB to 35 dB
Gain step	0.5 Db
Frequency	2.5 ppm
Max. instantaneous real time bandwidth	l6-bit sample width – 24 MHz
	8-bit sample width – 48 MHz
Max. I/Q sample	l6-bit sample width – 25 MS/s
	8-bit sample width – 50 MS/s
DAC Converter	2-channels, 400 MS/s, l6-bit
DAC spurious-free dynamic range	80 dB

Table l: NI USRP 292l Transmitter [1]

Frequency range	2.4 to 2.5 GHz; 4.9 to 5.9 GHz
Frequency step	< l KHz
Maximum input power	-l5 dBm
Gain range	0 dB to 92.5 dB
Gain step	2 Db
Frequency accuracy	2.5 ppm
Max. instantaneous real time bandwidth	l6-bit sample width – l9 MHz
	8-bit sample width – 36 MHz
Max. I/Q sample rate	l6-bit sample width – 25
	8-bit sample width – 50 MS/s
Analog to digital converter	2-channels, l00 MS/s, l4 bit
ADC SFDR	88 dB

Table 2: NI USRP 292l Receiver [1]

In this testbed, we consider channels only in 2.4 to 2.5 GHz and 4.9 to 5.9 GHz ISM bands as we do not need any licensing for these bands.

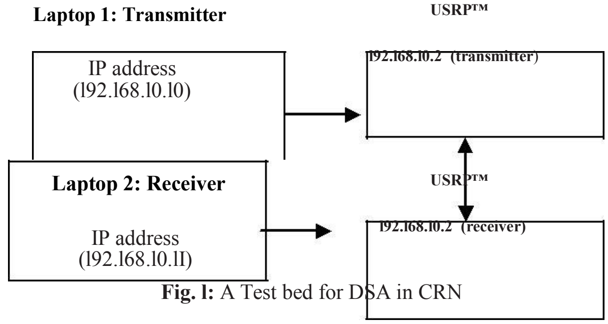


Fig. l: A Test bed for DSA in CRN

III. CHANNEL SELECTION FOR RENDEZVOUS

We use channel scanning methods to find a common channel for desired transmitter and receiver where receiver hops much faster than its transmitter for rendezvous. To find the signal we use energy detection technique and to find the intended transmitter w e u s e modulation techniques. They communicate in common channel for a given time slot duration after meeting in that channel. The SUs hop to another channel slot to avoid any jamming or interference to PUs although SUs can still stay in the same channel.

We implement two channel selection methods:

(a)Sequential channel scanning method

(b)Quorum based rendezvous method

In sequential channel selection method, the idle channel is identified using sensing algorithm or using external agent by both transmitter and receiver SUs independently. Then common channel between transmitter and receiver is found by SUs using those idle channels. In sequential channel selection method, transmitter starts its process for communication choosing a channel. The transmitter is detected using energy/power detection approach by receiver which uses sequential scanning process to find a channel. In quorum based channel selection approach, transmitter and receiver use matrix grid method to generate transmission and receiving matrices. In this approach, transmitter and receiver generate subset of the available channels so that receiver would not have to sense all channels like in sequential scanning. Transmitter and receiver confirm communication in a given channel for given time slot based on the signal energy and modulation technique. After finishing the given time slot, they start the quorum based channel selection approach for another slot. Until there are no more idle channels at all, this process will continue and the SUs finds common channel.

In order to detect whether there is any transmitted signal from transmitter we can use two hypotheses as

1. When there is no signal from SU-transmitter,

there will be just noise which can be written as

$$s(t) = n(t) \qquad H_0$$

2. To detect transmitted signal from SU transmitter, received signal at SU receiver can be written as

$$s(t) = g\,p(t) + n(t) \qquad H_1$$

where *g* is channel gain, *p(t)* is signal from SU-transmitter and *n(t)* is the additive white noise.

According to t h e hypothesis H_0 there is no signal (only noise), and according to the hypothesis H_1 the signal is present. To detect a signal, we compute power of the received signal in

$$s(t) = g\,p(t) + n(t) \qquad (1)$$

where *g* is channel gain, *p(t)* is signal from SU-transmitter and *n(t)* is the additive white noise.

We can use the power spectral density of p(t) and use it to compute the power (P_g) of the power type signal in (l) as [21]

$$P_g = \lim_{T\to\infty} \frac{1}{T}\left[\frac{1}{2\pi}\int_{-\infty}^{\infty} |G_T(\omega)|^2 d\omega\right]$$

In above equation when T approaches to infinity, the term power spectral density of p(t) can be stated as $S_g(w)$ and written as:

$$S_g(\omega) = \lim_{T\to\infty} \frac{|G_T(\omega)|^2}{T}$$

The power spectral density of power signal p(t) can be described as:

$$P_g = 2\int_0^{\infty} S_g(\omega)\, d\omega$$

In order to detect signal from SU receiver the received signal strength is compared with minimum threshold power (P_{th}). If $P_g > P_{th}$ then signal is

detected then SU-receiver can use modulation schemes to identify SU-transmitter signal in the channel. This process is repeated again to identify common channel between transmitter and receiver for the given set of channels.

shown in Fig 2 and if we are able to access any common channel in this selection, the SU-transmitter waits for SU-receiver after selecting common channel. SU-receiver on the other hand scans only common channels instead of scanning all channels. Legal grid method makes most reliable predictions by identifying common channel. [1]

1	2	3	4

In the following section we will discuss and compare channel selection for rendezvous.

A. Sequential channel selection for rendezvous

In Sequential channel selection scheme, SU-transmitter processes a suitable channel from a set of channels and waits till SU-receiver approaches to establish a communication link. During this SU-receiver which scans faster than its transmitter using signal strength detection and modulation detection approaches to find most appropriate channel by its intended SU-transmitter. After finding common channel they communicate with each other. In sequential process the receiver scans all the channels from given set of channels C = {$c_1, c_2, c_3 \ldots c_N$} until it find its desired channel or idle channel extinct.

This process creates a problem when transmitter is set to nth channel and receiver scans from 1 to n channel sequentially. To overcome this we have quorum based channel selection.

B. Quorum based channel selection for rendezvous

Sequential scanning scans each channel which results in power and time wastage, apart from this it creates problem for adaptive systems where transmitter moves at a slower pace than receiver and shifts systematically. Thus by the time receiver has sequentially scanned all channels and is about to reach common channel transmitter might change its channel and jump to other channels. In case of many idle channels this problem worsens. To avoid all these problems we study quorum based channel scanning where receiver carrier predictive channel hops and it selects channel only if senses signal strength in given channel.

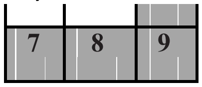
In quorum based channel selection for rendezvous selection we implement legal grid method which will reduce search space for idle channel for SUs. In this SUs get information about number of idle channel (I_N) and then creates a random matrix such that I_N = m × m that fits the grid. Similarly we can generate n × n matrix for receiver. Also both matrices can be equal.

To find any common channel we first start with last row and column to find common channels as

5	6	7	8
9	10	11	12
13	14	15	16

I

1	2	3
4	5	6



II

Fig 2: Matrices of idle channel for Legal grid based channel selection

In this 4×4 matrix consider last row and column

and compare it with 3×3 we find channel 8 is **common. For second last column and row we don't**
have any common channel therefore transmitter and receiver will have to either sense some other set of channels or wait for another common channel. Now in case we select second last row of I and last row of II in fig 2 we have {3, 7, 9} as common channels. When transmitter and receiver find similar channel, it should select common channel and wait for receiver to negotiate. Now SU receiver would scan only these channels which serve as advantage of quorum unlike in sequential where it has to scan all channels. Thus this utilizes time, reduces search space and makes communication hastily.

IV. THE ALGORITHMS

This section will discuss algorithms for proposed test bed.

A. Sequential channel selection for rendezvous

In this all channels are caned by transmitter and receiver sequentially and idle channel for communication is established. We use LabView and MATLAB scripts as software to control NI USRP. The algorithm is as described
Algorithm 1:

Algorithm Sequential Channel Selection / hopping

Identify idle channels and **store** them in carrier [] array;
Initialize sequential hopping feedback variable **out_index**;
define power variable pW;
Check if there is enough received signal strength **If**
pW>p_{thres} ; threshold power
MAINTAIN channel;
CHECK for modulation type used by transmitter STAY in that channel if transmitted is intended
one.
return channel index;
OTHERWISE hop to another channel **else**
Channel index++;
end

If SUs has no channel selected for given band it will not select any common channel. While using NI USRP we can access 2.4 GHz to 5 GHz which comes in ISM channels therefore we can implement test bed under this band.

V. CONCLUSION

In this paper we have discussed a test bed to implement dynamic spectrum access using cognitive radio network which

B. Quorum based channel selection for rendezvous

In this transmitter selects for predicted channels and waits for its receiver to establish link as explained in section III-B. It scans idle channel using quorum detection approach. The algorithm [1] stated is as shown:

Algorithm 2:

Algorithm 2 Quorum based channel selection/hopping

Identify the number of ideal channels **n1** and **n2** at SU Transmitter and SU Receiver.
Generate two matrices **A1** and **A2** with mxm dimension and nxn dimension with **n1**=mxm and **n2**=nxn for the size of **n1**
For the size of **n2**
LOAD **A1** elements in legal grid as in **Section III-B**
LOAD **A2** elements in legal grid as in **Section III-B.**
end for
end for
Start with last column & last row until first row & column for all the elements in A1 of dimension mxm
A1q=LIST the last row and last column elements **for** all the elements in A2 of dimension nxn
A2q=LIST all the last row and last column elements
A1A2q= find the intersection A1q and A2q
If A1A2q is empty go to second last row and second last column and repeat the process as mentioned in Section III-B
Apply algorithm 1 for common channel in **A1A2a** set
Repeat this untill process meets no common channel or first row &column of the matrics.

uses sequential channel selection scanning and legal grid based quorum based scanning to find a common channel foe peer-to-peer based communications for SUs. Test bed discussed can be created using NI USRP and program USRP devices using LabView and MATLAB. We have also discussed detailed comparison of sequential channel selection scanning and legal grid based quorum based scanning. Legal grid based quorum based scanning approach proves to be an efficient approach which utilizes lesser time and is more adaptive to CRN for DSA. This paper could be extended in implementing this test bed practically and we can test more channel selection algorithm using similar test bed.

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