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Spectrum sensing approaches in cognitive radio network

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ABSTRACT

Due to fixed spectrum allocation phenomenon (FSA), spectrum agreement failed to satisfy the demanded of new applications. However, cognitive radio is approached for utilizing the spectrum and for overcoming resources deficiency. Day by day, number of radio spectrum users is increasing as life tends towards new technologies in all sectors; so, even those users of licensed band are demanding larger radio spectrum. Users may get assigned into other bands to balance the radio spectrum congestion. In this paper, radio spectrum is sensed for voids detection and secondary user assignment. Two approaches are discussed for spectrum sensing, more likely, Underlay and Interweave spectrum allocation. This paper argues the performance metrics of each in terms of queuing time minimization and throughput enhancement.

Keywords: FFT, FSA, CR, IEEE 802, AWGN

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1. Introduction

As other sources of asset, Radio spectrum is witnessing higher demand as today life tends to depend widely on communications to facilitate most life activities. Efficient spectrum utilization has become insisting challenge for communication professionals. Cognitive radio was approached to ensure best utility of spectrum, it works in dynamic fashion to use spectrum with no interference. The electromagnetic spectrum is deploying the range of frequencies starting from 2.5 Hz through 3.5 Giga Hz, however radio spectrum is overcome part of electromagnetic spectrum, the telecommunication is underlying with electromagnetic signals (waves) which is well known in this domain as radio wave, it can travel by different physical mediums such as wire or wireless. Organization such International Communication Union (ITU) went to regulate the usage of this spectrum and paid efforts to avoid interference between different players participating the same. Furthermore, local authorities in each country may have their regulations as well to be applied on those bodies willing to use radio spectrum such like accessing any other national fortune, land borders, space border or sea border [1]. ITU has set around fifty services of communication channels as given in [2], sometimes, radio channels are leased to some service providers such as mobile operator so that particular frequency will be used by those bodies only and last may be called as licensed user. Similarly, TV bands and broadcasting bands are also allotted to the working bands and called licensed user. So, spectrum used by cellular applications may call as cellular spectrum and that which used for television broadcasting is known as television band or spectrum. Recently, radio spectrum is suffering of congestion as users are increasingly demand a radio resources [3], that is caused by large users and few resources (limited spectrum). However, time to make efficient use of radio resources is yet. Techniques like, frequency pooling, spectrum reuse, spread spectrum and cognitive radio are on table for addressing the challenges of spectrum congestion. In general, two main players are needed to work out, licensed user which is defined by ITU as such user that allotted to fixed band and can transmit freely within that band without interfering into other bands transmission by any means; unlicensed user, is that candidate which needed to access the licensed band and either allotted to some other network and want to transmit across new network (foreign candidate); one more definition is licensed band which was defined as the range of radio spectrum (frequency limited range) that occupied by licensed users. Cognitive radio is that approach which allows secondary users to share the transmission with licensed users without harmful effect for any. A Cognitive Radio network is analyzed in this paper for optimizing the average throughput of the secondary spectrum candidates.

2. IEEE 802.22

Wireless Regional Area Network (WRAN) is developed by IEEE 802.22 standard that supports digital television broadcasting. This protocol is established to serve small geographical regions and limited number of users that's why it is subjected as regional [4]. Cognitive radio first network is conducted with this protocol which applied network ability to reuse white spectrum in small geographical areas with minimum interference between network candidates [5]. The technology of cognitive radio that was stated in details on previous researches and is referred to wireless regional area networks that guarantee the spectrum sharing between licensed and unlicensed users with no harmful returns to licensed users; however, this standard supports small power applications like wireless microphone and TV broadcasting (analogue and digital television), this standard had published by IEEE on late 2011 [6][23]. IEEE 802.22.1 and IEEE 802.22 WG is consecutive standards developed for averting the interference of low power applications and to enhance the previous standard so that some applications of wireless local area networks (WLAN) are also involved to participate this technology. For first instant, IEEE 802.22 begins with point to multiple point communication (P2MP) [7] that applied on digital television network that formed by installing premises attached equipment (PAE) with is connected directly to network base station (base station subsystem BSS) by means of wires. The BSS is responsible to form the network traffic and initiate spectrum management. WRAN based digital television broadcasting with cognitive radio capabilities is working by make PAE to gather the information about channel status (which is so-called as spectrum sensing); with help of signaling capability, [8] gathered information is directed to the base station sub system (BSS) which has the decision-making capabilities for channel allocations and user mobility. It is important to notice here that user assignment to new hole is cauterized and done by base station. However, user needs to be within network coverage in order to participate this facility. Users can only sense the channel and forward information to the higher layer [9].

3. Spectrum utilization

Cognitive radio network aims to share the spectrum between primary and secondary users where primary user is not getting any harmful effects in return. However, previous studies revealed that spectrum sensing is essential operations in cognitive cycle [10] [16][24]. Secondary user needs to sense the spectrum periodically to confirm the vacancy. Radio spectrum is divided into smaller bands which are used by different applications, those applications are known as licensed users who are permitted to access those bands at any time and transmit freely but! need to avert any harm on neighborhood; since CR network is assigning the same spectrum bands to secondary users at the time primary user is idle, CR network need always to now about channel conditions to assign secondary user for vacant bands only and avoid interference with licensed users [11],[25]. Sensing of spectrum is the process which in turn responsible to provide the channel information to the higher layer of CR stuck. Channel status may be full with licensed users or may be vacant, in other word, channel is practically is experiencing noise such as Additive White Gaussian Noise and fading effects, channel undesired participants can be listed as: AWGN, Fading, etc. [12] [17],[26]. Such disturbances may degrade the channel performance while it's taking place in radio bands. Spectrum sensing may result whither primary user is present or is vacant so that following hypothesis are satisfied: H0: procedure may yield this outcome if channel is vacant so noise components are presented only.

$$H0 = n(t) \tag{1}$$

Otherwise, H1 hypothesis may be yielded which states that channel is experiencing a demand by primary user, so hypothesis may return noise component plus signal detection as follow:

$$H1 = n(t) + S(t) \tag{2}$$

Where n(t) is representing noise component and s(t) is representing signal from primary user which declared that primary user is existed in that particular radio band. Such information are necessary to avoid interference between primary and secondary user.
The available approach to investigate the radio spectrum is energy detector which makes use of power spectrum density PSD of the channel which gives all frequency components. Results of PSD can be forwarded to decision taker circuit that validate whither the channel is vacant and only noise components are appeared so results will more likely become as H0, otherwise, H1 may be yielded. The outcomes of this paradigm can be expressed mathematically as:
$H[n]$ is the impulse response of system and $X[n]$ is the input sequence which is the channel information, hereafter, convolution can be applied to get the decision as following.

$$Hx[l] = \sum_{l=-\infty}^{l=+\infty} X[l].H[n-l] \quad (3)$$

3.1. Radio spectrum modelling

Three arguments are inquired during this phase: the working bandwidth, required number of licensed users and simulation time. In here, bandwidth is divided equally among the primary users so that following assumption is yielded: (PU-BW= total BW/total PUs) [13] [14] [15]. Simulation time is considered here to study the random behaviors of primary user band occupancy; hereafter, program will calculate each licensed user frequency and prepare a frequency modulation to transmit all those users into radio medium. At the end of this paradigm frequencies are made available and public variable in vector form to be used in further procedures also, transmitted signal is prepared for 800 Hz bandwidth, 8 primary users and 80 seconds of running time; program supposed to produced F-bands= [100 200 300 400 500 600 700 800]. AWGN is added to the set above in order to realize the ground constrains of the network.

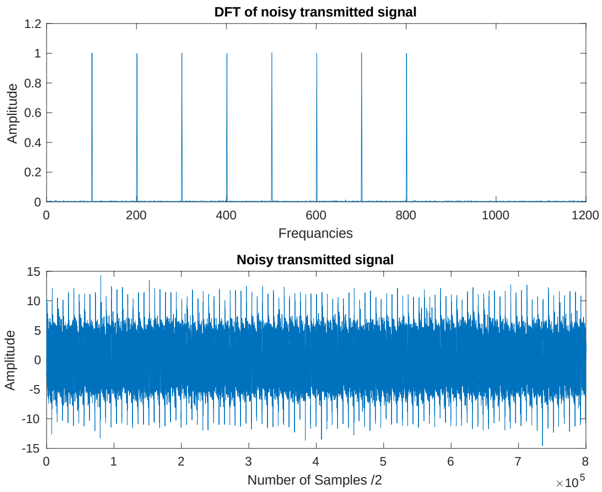

Figure 1. Licensed users generation (RF model results)

4. Behaviors Modelling

It is well known that primary users are occupying the channel as full occupancy, 100% for all time. Now to approach the reality situation, more likely, primary user may quit the channel at any time and may also return to the channel after some time (unknown and un-controller). The reach user is taking over for a time (Tw) and may be return to occupy the same channel after Tw second. Hence, those factors are modulated as uncontrolled random variable. Each user can use the license band for Tw and exit after completion of that period, Tw is never identical for any two candidates unless other criteria are recalled. According to the time constrains, program is instructed to initiate a matrix called as behaviors matrix; it contains of binary information that is stating the frequency availability for each time slot during the simulation. Figure 2 demonstrates the process of user behaviors modelling.

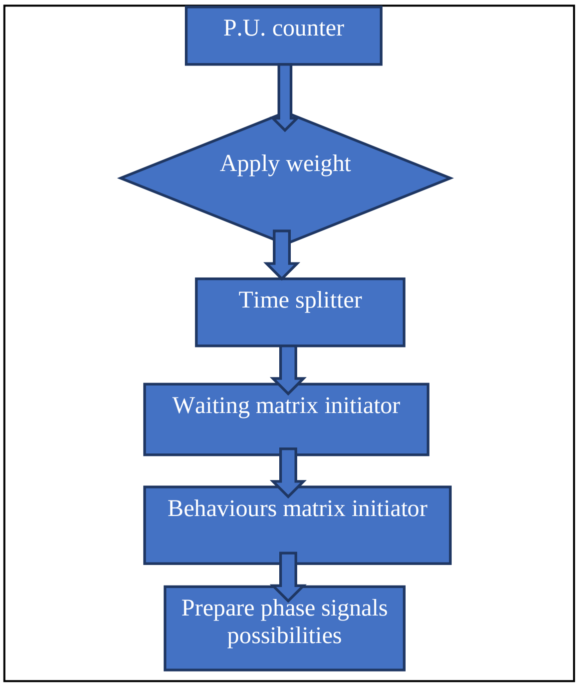

Figure 2. Model of behaviors generating for licensed users

4.1. Cognitive users modeling

During this paradigm, number of cognitive users is inquired, we started this phase of program by feeding a double of primary users' numbers as cognitive users, however, let us say 16 users are willing to use the licensed spectrum. As per FSS regulations, the cognitive users can use a white band if and only if that band is declared vacant. Considering this assumption, we may establish a new matrix corresponds to secondary user's activity and in accordance with primary user's behaviors, Practically Activity matrix is the reversed version of behavior matrix as depicted in Figure 3.

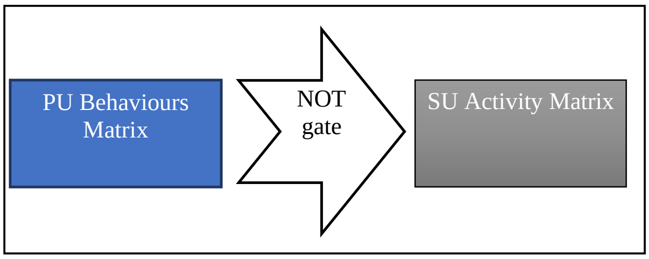

Figure 3. The prediction of Secondary users behaviors

5. Results and discussion

After continuous sensing of the available bands, network may be tested about how to adopt a suitable approach to assign secondary users into white band. However, for 'n' number of secondary users, spectrum availability is totally dependent upon primary user; believing in this fact, secondary users can share only allowable portion of white band which may be permitted by primary user base station. New constrains may consider in this phase of the system such as time delay and throughput. Time delay is resulting due to user's mobility and number of candidates willing to share the band. Obviously, secondary user needs to wait its role to participate the band alike rest candidates; if the present number of candidates is small, user may get chance

to transmit shortly unlike otherwise. In this paradigm, two techniques have been proposed to share the spectrum between primary and secondary users: underlay and interweave spectrum sharing.
Two outcomes are demonstrated in thereafter, the transmission delay and throughput; the time consumed by secondary users (each) during functional time (simulation slots) prior to that user turn of transmission is called as transmission delay. Form the other hand, number of secondary users that delivered to the destination (without fail) while 'm' iteration called as throughput. However, as network is functional, primary users are activating normally so their activity and behaviors must be continuously watched. secondary users are in standby, waiting the chance to participate the spectrum. Known that spectrum sensing was done by secondary user control station (base station, back office); transmission delay is counted for each candidate and then throughput from each iteration is yielded. Results are recorded to conclude this complex process; trade off was found between the mentioned techniques in terms of time and throughput.

5.1. Queuing time monitoring

Primary and secondary users may share the white band depending on spectrum sharing techniques which governing this process. For underlay spectrum sharing, both primary and secondary users are transmitting at same time but secondary users have to limit their activity to the level that ensure no interference with licensed users; however, this may force secondary users to develop queues. As Figure 4 is revealing, at any consecutive candidates sharing same licensed slot, one of them can start transmission first (First Come First serve) and thereafter the next user may start. In here, next user needs to wait till previous user leaves the band.

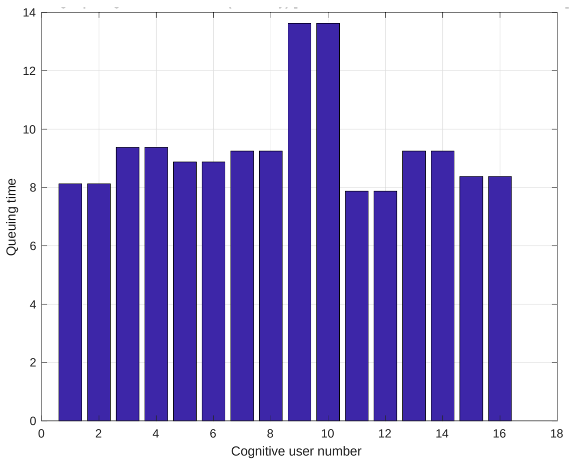

Figure 4. Underlaying technique average queuing time experience by secondary users

Figure 5 depicts the interweave spectrum sharing technique which permits transmission only if that particular band is declared vacant and not otherwise. Such arrogant roles may reduce total secondary candidates sharing the band so no queues will develop and user need to sweep the spectrum periodically to get in and quit the band immediately before primary user returning. So, transmission delay is lesser even though higher transmission rate. Users can only access vacant holes of spectrum all other users may get discarded.

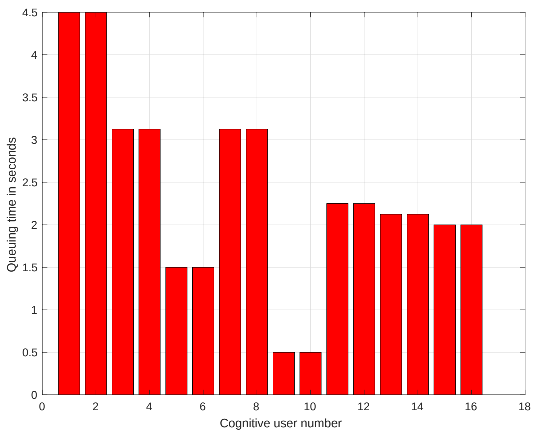

Figure 5. Interweave technique average queuing time experience by secondary users

5.2. Throughput

Starting with 18 secondary users, in case of underlay spectrum sharing they can transmit simultaneously with primary users but care need to be taken for interference pretension, such may develop time delay prior the transmission but throughput is enhanced here, which means the actual number of users participating the band with respect to total available secondary candidates is bigger. Figure 6 demonstrates throughput in each iteration (eight iterations with ten seconds per each) and 18 secondary users. The throughput at interweaved technique is lesser for similar traffic conditions as in Figure 7.

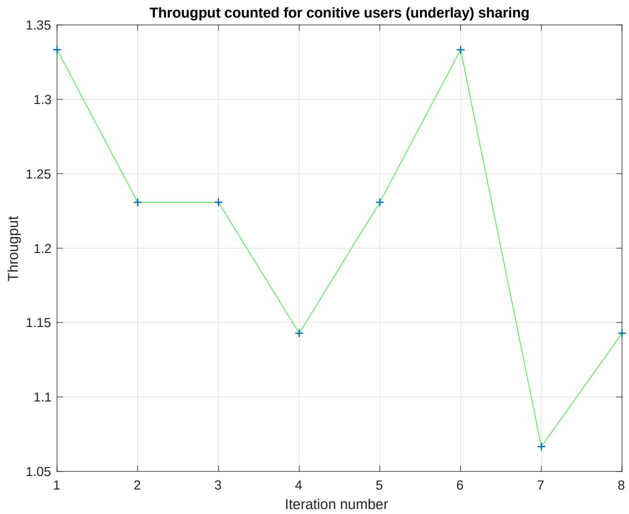

Figure 6. Throughput of the cognitive network when underlaying spectrum technique is used

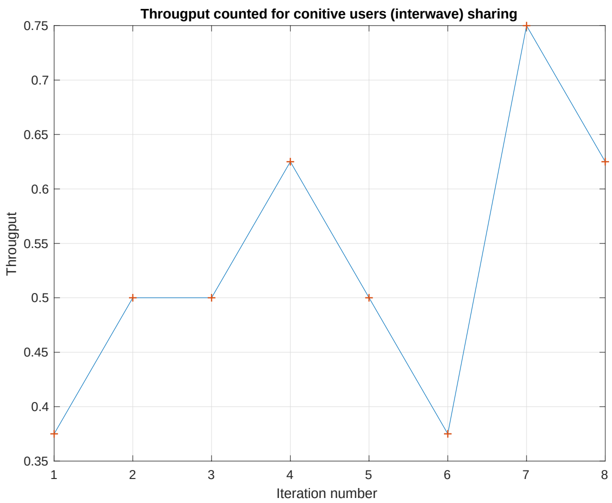

Figure 7. Throughput of the cognitive network when Interweave spectrum technique is used

6. Conclusion

Cognitive users are participating the white band either by transmitting alongside with primary users or waiting until the hole is getting vacant. During the period of transmission, the behaviors of primary users are studied for determining the spectrum occupancy status. The activity of primary users is simulated as random variables due to uncertain behaviors from time perspectives. Issues like channel noise and fading effects stand as interrupters of spectrum sensing which make spectrum holes to appear busy due to such incidents. CR network is modelled by using Matlab software so that both primary and secondary users can sense the spectrum by Energy detection method and share the spectrum effectively by employing the approach of waiting time estimator which provides behaviors and activity matrixes. Candidates are made to share the spectrum and hereafter transmission delay and throughput are examined when underlay and interweave spectrum sharing were in use. Time estimator algorithm is used to reduce computing budget and latency to obtain a trade-off between throughput and transmission delay.

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