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Research paper

Dynamic approach for spectrum sharing in cognitive radio

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Abstract

Due to fixed spectrum allocation phenomenon (FSA), spectrum agreement failed to satisfy the demanded of the evolving technolo-gies. However, cognitive radio has approached for utilizing the spectrum and substituting resources deficiency. The number of radio users is tragically increasing since human turns technologies in all sectors; 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, we proposed model to overcome radio deficiency. This paper is highlighting the spectrum sharing performance constrains. Time delay and throughput are studied under differ-ent spectrum sharing techniques.

Keywords: Spectrum sensing (SS); Frequency Division Multiplexing (FDM); Cognitive User; Licensed Band (LB); Underlay; Interweave.

1. Introduction

Like any other fortune, radio spectrum is presenting higher de-mand 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 frequen-cies starting from 3 Hz through 3 THz, however radio spectrum is overcome part of electromagnetic spectrum, the telecommunica-tion 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 be-tween 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 spec-trum and that which used for television broadcasting is known as television band or spectrum.
Studies revealed that spectrum is being taken over by licensed users and such users are only utilizing twenty percent of available spectrum. Today, organizations seek connectivity with each other by means of advance technological trends in which demand high usage of radio spectrum. Obviously, most of such users are not adaptable with licensed band barriers. The term barrier may refer to bulk of reasons alike far expensive cost which is unbearable by individuals and small entities (unlicensed users) [3].
However, secondary users are available and intended to utilize these spectrum holes. The challenges are arisen when both li-censed users and unlicensed users are willing to use the spectrum at the same time. This paper is proposing technical strategies to overcome such incidents and utilize the spectrum fairly between licensed and unlicensed bands. Under weave and overlay spectrum sharing techniques are employed to achieve optimum time and throughput at the paradigm.

2. Protocol architecture

This standard had published by IEEE on late 2011. 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 tech-nology. For first instant, IEEE 802.22 begins with point to multi-ple point communication (P2MP) 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 responsi-ble 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 signalling capability, 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 cau-terized and done by base station [4]. 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. Figure 1 depicts the architecture of WRAN network.

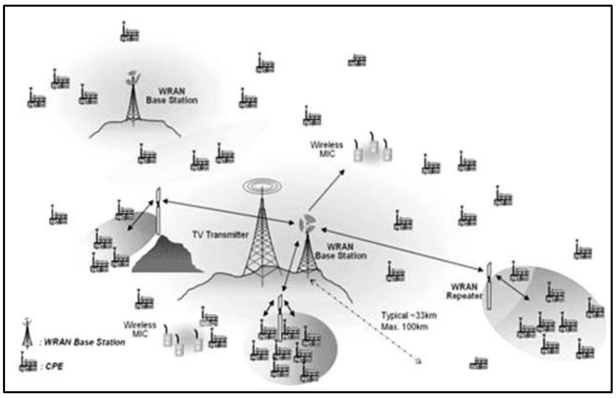

Fig. 1: The Wireless Rural Area Network Planning.

2.1. Medium access layer

Cognitive radio (CR) facility is integrated in this layer to play the role of spectrum access and sharing management. This layer has adaptive nature to handle with dynamically changing spectrum conditions. Two different frames are formed in this layer: frames and super-frames. The latter is created by sub-station and is forwarded to the suitable channel where interference level is within tolerance. In turn, the PAE may receive this super-frame as channel permits and declares availability. PAE may add sensing information to the header of this super-frame and transmit it back to the server (base station) which starts the required steps to update channel availability list [5].
Base station and user equipment are doing two types of spectrum management which used to identify the channel status. In band channel sensing to be done through selected single channel and used to provide information about that particular channel; form the other hand. Out-band sensing is performed by user equipment for all channels. In medium access layer, channel is sensed with two different methods: fast sensing which lasts for one millisecond and fine sensing that takes longer time around 26 milliseconds and relies on fast sensing information. Both sensing techniques work to validate the fact that no collision will occur in any particular channel and they used in protocol stack to avoid the interference.

3. Spectrum sensing

Sensing of spectrum is the process which is responsible for providing the channel information to the higher layer of CR stack. Channel condition may be full with PUs or may be vacant. Let H0 to be the 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 PU, 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 PU which declared that PU is existed in that radio band. Such information is 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 maker circuit that validates whether the channel is vacant. 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 follow:

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

Spectrum sensing is done according to above hypothesis test to validate primary user (PU) availability in the spectrum.

2.2. Underlay technique

To share the spectrum between primary and secondary users with fair, two technologies may be used in this thesis: underlay spectrum sharing and interweave spectrum sharing techniques. In the first technique, both users can transmit simultaneously using the available spectrum bands but SU needs to maintain the tolerance level for interference. Within underlay technique, SU may draw a moderated throughput in which users participating the band are maximized under transmission agreement which states that only permissible bandwidth can be shared with SUs which means users to come first is served first and remaining users may maintain queues, so underlay technique has bigger time delay [9].

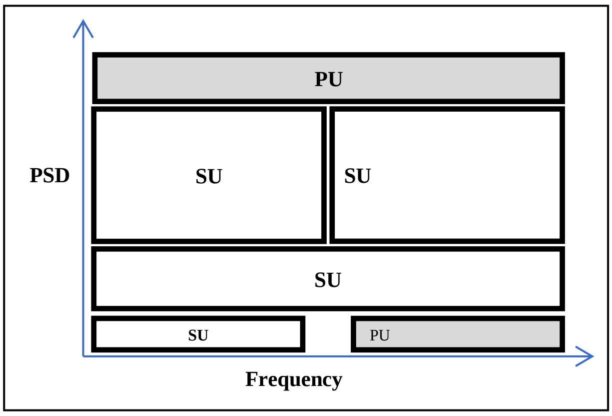

Fig. 2: Underlay Spectrum Sharing Technique as Appeared In Power Spectra.

2.3. Interweave technique

Underlay procedure is reversed in case of interweave sharing technique where transmission can be achieved only when PU is not transmitting; the SU hereby start signalling at the vacant bands in the place of absent of PU. This method of transmission agreement may ensure lesser transmission delay as users do not need to stand in queue for transmission opportunity. On the other hand, only few users among secondary group can participate the band so throughput is lesser in here [10].

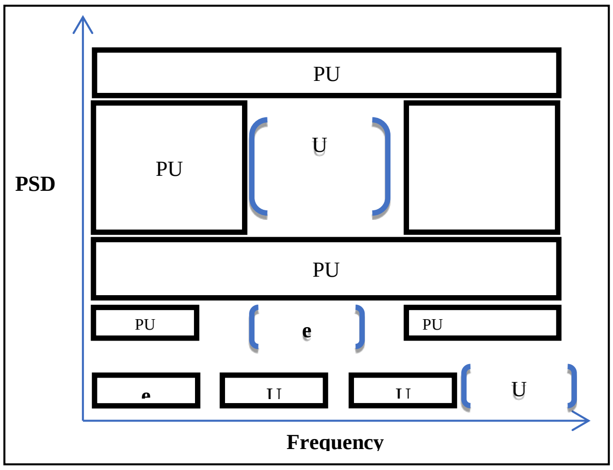

Fig. 3: Interweave Spectrum Sharing Technique as Appeared in Power Spectra.

4. Practical model

Experiment is begun by providing a '20' of primary users and allotting them into licenced bands where they can use the band freely. Number of secondary users '12' are also modelled with intention to make them transmitting over the same bands. Transmission interference is required to set minimum. Spectrum sensing may require to be done for error free transmission assurance.

After sensing all available bands by secondary user's base station, new model is needed now to adopt a suitable approach to assign SUs white band that is used by PUs. However, for 'n' number of SUs, spectrum availability is totally dependent upon PU. Because of this, SU can share only allowable portion of white band which may be permitted by PU base station (signalling centre/ where control signals are exchanged between the base station and mobile unit through signalling channel). Prior of user transmission, some constrains alike: transmission delay and throughput limitations are required to be addressed. Time delay results by user's mobility and number of candidate willing to share the band. Obviously, SU needs to wait for its role to participate the band alike rest candidates; if the present number of candidate is small (adaptable), user may get chance to transmit shortly unless otherwise. In this paradigm, two techniques have been proposed to share the spectrum between PUs and SUs: underlay and interweave spectrum sharing.

The logic of spectrum sharing method which defined earlier may be used to implement their model and display results on thereafter i.e. transmission delay and throughput. The time consumed by secondary user (each) during to transmit on the said channel during simulation slot is called as transmission delay. On the other hand, number of SUs that are able to share the licenced band effectively without termination (without fail) while 'm' iteration is called as throughput. However, as network is defined as functional, PUs are supposed to be active. However, the behaviours of PUs can be visualized by spectrum monitoring model. Meanwhile, SUs are in standby position and are ready to participate the spectrum. Known that spectrum sensing was achieved by secondary user control station (base station, back office), results may be monitored at this point. Ultimately transmission delay is counted for each candidate and then throughput per iteration is obtained. However, there is trade-off between the delay and throughput in underlay and interweave techniques.

5. Results and discussion

Primary (PUs) and secondary (SUs) users may share the white band depending on spectrum sharing technique basis governing this process. For underlay spectrum sharing technique, both PUs and SUs are transmitting at same time but SUs have to limit their activity to the level where there is no interference with licenced users. However, that may force SUs to develop queues.

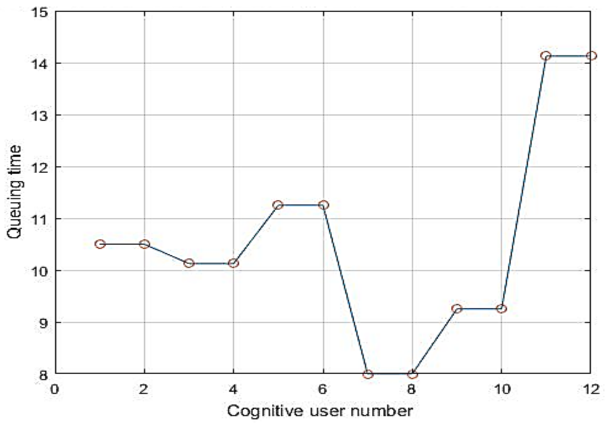

Fig. 4: Transmission Delay as Per Undelay Spectrum Sharing.

As revealed by Figure 4, at any consecutive candidates sharing same licenced slot, one of them can start transmission first (priory is given to the first arrival) and after next user may start. In here, next user will need to wait till previous user leaves the band. In Figure 5, if cognitive user or SU1 waits for 10.4 second, then user 2 will wait 20.8 second to take over the band. In the same figure, it is also shown that band of users 11 and 12 may experience of the higher interference comparable to other bands as PU is occupying the band for long time. Due to that, lesser number of SUs can share this band. In other word, candidates need to wait for longer time in their queues. This logic remains same more likely bigger queues are developed as transmission rate getting high; Figure 5.

Looking at Figure 5, interweave spectrum sharing can permit transmission only if particular band is declared vacant (never otherwise). Such arrogant roles (interweave spectrum sharing regulations) may suppress/limit the most of secondary candidates from sharing the band. However, no queues will be developed and user will need to sweep the spectrum periodically to get-in. User will need to quit-out of band immediately before PU returning. Hence, transmission delay is lesser even though higher transmission rate. Depending on vacant band capacity, some SUs can get access to that spectrum and all other users may get discarded.

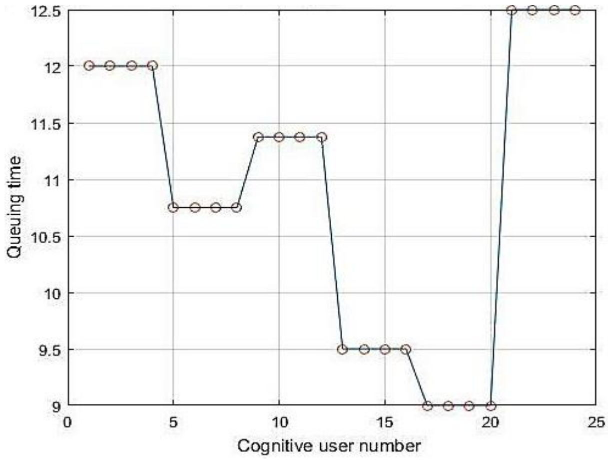

Fig. 5: Transmission Delay as Per Undelay Spectrum Sharing.

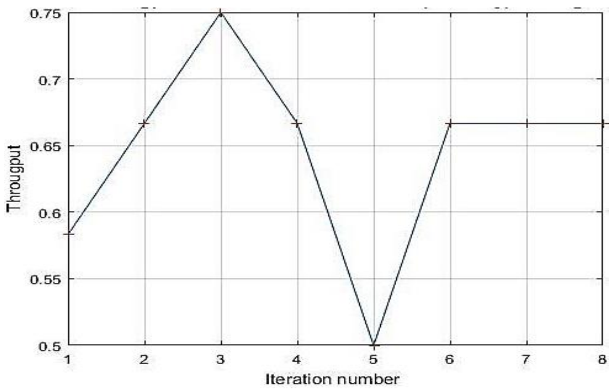

Fig. 6: Throughput VS Iteration Counted for Secondary User 12 during Underlay Spectrum Sharing Technique.

Starting with twelve secondary users (SUs), within underlay spectrum sharing they can transmit simultaneously with primary users (PUs) but care should be taken for interference avoidance. This may develop time delay prior 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 twelve SU. On the other hand, interweave spectrum sharing is experiencing lesser throughput for same number of secondary candidates comparable to underlay spectrum sharing as in Figures 7. Reason behind these episodes is related to internal mechanism of these particulars, more likely vacant bands only can be accessed by SUs during iteration time.

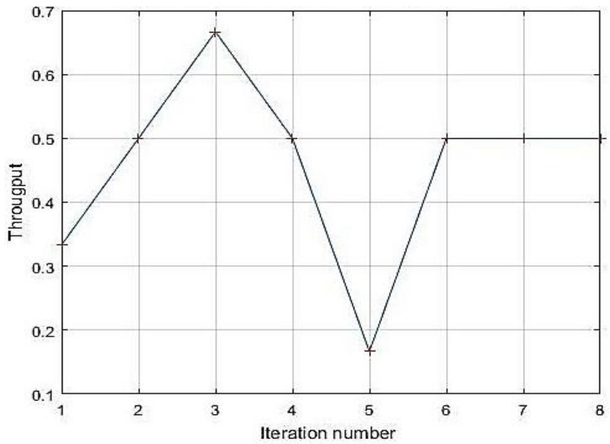

Fig. 7: Throughput vs. Iteration Counted for Secondary User 12 during Interweave Spectrum Sharing Technique.

6. Conclusion

For cognitive radio network, secondary users seek to share white bands unless collision is taking place. Channel is periodically sensed by cognitive network to find the vacant holes. Spectrum sharing is adapted to serve different nature of applications and fulfil of their requirements. Time delay and delivery throughput are extensively studied with efforts to identify the sharing technique that suitable for different applications. The proposed approach may minimize the risks of user mobility and may face the challenges of transient state channels. For applications of different nature, spectrum sharing technique would be selected according to prototype requirements, more likely, applications of real time transmission are involved interweave spectrum sharing technique which provides lesser transmission delay and those of high throughput requirements are involving underlay spectrum sharing technique which satisfies the application requirement. Simulation results revealed that minimum transmission delay is achievable by employing interweave spectrum sharing and maximum throughput can be gained from underlay spectrum sharing.

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