*International Journal of Engineering & Technology*, 7 (3.20) (2018) 935-940

International Journal of Engineering & Technology

*Website: www.sciencepubco.com/index.php/IJET*

***Research paper***

# Double Auction Framework to Manage the Secondary Users in Cognitive Radio Networks (Crns)

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**Abstract**

Cognitive Radio Networks (CRNs) is an emerging concept in wireless access between the users. The CRNs intend towards effective utilization of frequency spectrum when the licensed user is not utilizing the spectrum. The CRNs are vulnerable to security issues like general networks. Security provisioning plays a vital role in CRNs for authorizing the information being shared among the legitimate Primary Users (PUs) and the opportunistic Secondary Users (SUs). This work mainly focuses on the mitigation of selfishness among the unlicensed users during the presence of multiple malicious users. In this work, we consider a beam-forming based Dynamic Spectrum Leasing (DSL) [34] concept to enhance the spectrum utilization for the communication between the primary and secondary users. We propose a Double Auction Framework (DAF) for improving the Selfish SU detection rate during the presence of malicious users to improve the number of opportunistic Users without creating hindrance to the legitimate User. The Simulation results reveal that the DAF-DSL based scheme provides effective spectral gains comparing with the baseline scheme for the secondary users spectrum utilization.

***Index Terms:*** *Cognitive Radio Network, Dynamic Spectrum Leasing (DSL), Spectrum Sensing Data Falsification (SSDF) attack, Double Auction Framework (DAF).*

## 1. Introduction

The radio spectrum is the major resource for wireless communication systems and is a limited resource because of its inefficient usage and it is mainly used for various wireless applications and services. The Fixed Spectrum Access (FSA) policy has legally taken by spectrum management, which allocates each and every part of the spectrum with fixed bandwidth to licensed users. Cognitive Radio (CR) [33] allows us to adopt the dynamic spectrum management. The number of users in the spectrum increases day by day that leads to spectrum scarcity problem in many countries. Thus, CR [26] is one of the most promising technologies for future wireless communications. CR changes its operational parameters based on the environment it is operating. This technology shares the frequency bands of a legitimate user to the opportunistic users with certain limits. The CR operation can be understood from the Cognitive cycle which has three important phases, i) sense the spectrum, ii) learn about the network requirements and iii) adapt to the environment. The overall effective spectral utilization depends on the Quality of service needs for the authorized users. The legitimate users can do spectrum sharing [37], which has full privilege to share the frequency band to opportunistic users.

## 2. Related Work

### A. Existing problem and solution

Facilitating efficient and secure communication in CRNs among the users by dynamic spectrum leasing [1], [16], [17], [18], [28], [35], [37], [39] and allocation schemes has brought a lot more attention recently. [1] Proposed a spectrum leasing model for cooperating between secondary users. [16] Proposed a cooperative communication aware spectrum leasing by the primary user which uses the unlicensed users to full advantage as cooperative relays. In [17] a system design center selects a bid for the primary channel based on channel state info of SUs. [9] Xiaoyan Wang proposed a truthful nonmonetary double auction framework towards the secure communications for the Cognitive Radio Network where Primary Users and Secondary Users will be auctioned once. [19] A dynamic spectrum leasing based method is implemented along with distributed beamforming [38], [40] to relay the information of primary and secondary users. From the related work, it is obvious that the cooperative [42] spectrum sharing and fixed leasing results in poor spectrum management. To overcome these shortcomings, the Double Auction Framework based Dynamic Spectrum Leasing (DAF-DSL) method is presented.

### B. Dynamic Spectrum Leasing

In this work, we represent an auction-based model for Dynamic Spectrum Leasing [36] in the licensed network, which shares the frequency bands to the secondary users for communicating with each other by a stochastic geometry. The licensed user can improve its two-way communication with the help of relays. In this system, the licensed user is ready to share its frequency band [29] with the opportunistic receivers. In this work, we propose Quality of service for the two systems with and without leasing [21] as far as the information rate and better execution. Furthermore, we expand the safe information exchange between both the static and dynamic Cognitive Radio Networks [11]. At this point, we consider CRN systems, which has numerous licensed Primary User and the unlicensed Secondary Users. In static Cognitive Radio Network, we focus the current circumstance that licensed users and unlicensed user act each other in a solitary auction. In dynamic Cognitive Radio Network, a scenario where the information exchange between them in multiple rounds [30]. It is considered that the Primary Users joins the network at the beginning of the auction and stays in the system until the auction completes. The arrival of Secondary User is random during the auction. [13].Here the Secondary Users are prepared whenever the primary users leaves the system [46]. To facilitate this a Double Auction Framework (DAF) based dynamic spectrum leasing is presented.

The key commitments of this work are as follows,

•Double Auction Framework (DAF) is the primary framework to be utilized for the communication of static and dynamic cognitive radio network in a secure way, by assessing contemplations in different non-unselfish Primary and secondary users [47].

•DAF mainly focuses around the security of the secondary users during auction design. Moreover, singular levelheadedness and cost balance are additionally ensured,

• DAF assess all throughput and channel usage proportion by reproductions. We contrast the proposed work and standard plan and perfect plans, to consider both the execution gain and the effects of financial properties are examined.

•The proposed structures enact the clients to take part in the sale is completely non-monetary, in this manner evades a few issues identified with cash exchanges.

The rest of the work is organized by implementation of the Dynamic Spectrum Leasing (DSL) scheme to detect the attacks and to check for improved spectral efficiency with increased number of secondary users without affecting primary users. The Double Auction Framework is proposed to mitigate the effect of selfish user presence to increase the spectral strength for bi-directional communication and to protect the primary users with accuracy based.

## 3. System Model

We consider the system model with a static Cognitive radio network comprising of a main base station b, Primary user set P = {1· · · · · l, · · · · · L}, Secondary User set S = {1· · · · · o, · · · · · O} with their corresponding receiver as{R (1), · · · R (n), · · · R (N)}. The number of primary users considered in the auction is limited to 5, the number of secondary users considered in the auction process is 30. The arrival of PUs is pre-defined in the network but the SUs arrival is considered dynamic. In the licensed network consisting different channels (Q channels), the base station facilitate L licensed Users to communicate the information among them. We consider that an equal channel for Q channels to allow the licensed users, opportunistic user and base station to trade their data [48].

In static Cognitive radio network, we consider the collaboration among licensed users and unlicensed Users in a single round. In the proposed model, a single round consists of schedule vacancies, closeout opening to execute the auction process and transmission space is utilized in PU and SU transmit their information to their coveted capacity [25]. Normally, the transmission opening separation is higher than the closeout space. The transmission space with built up length is valuable partitioned into two stages. Helping stage and Rewarding stage. In the helping stage, a small amount of the communication space is used for the legitimate users for secure correspondence. To expand the auxiliary clients with the assistance of Amplify and Forward relay (AF), to enhance signal strength in the systems [45].

### A. Signal Propagation Model

In signal propagation show the got signals basically depend upon the quantity of various ways from which the signal achieves the goal end (blurring), different dissipating of the flag which will prompts varieties in the nearby mean flag levels[43] (shadowing), separation may subject to way misfortune. The Nakagami-m dissemination gives a far-reaching demonstrating to the fading environment with various estimations in the fading channel. A lognormal distribution is calculated using shadowing [44].

$$\mathbf{f_H(H) = \frac{1}{\Gamma(k)(\theta_0)^k}\, H^{(k-1)} exp\left(-\frac{H}{\theta_0}\right)} \qquad (1)$$

Where $k{=}m_s$ and $\theta_0{=}\Omega_0/m_s$ with moments
$E[H] = k\theta_0{=}\Omega_0$
Var $[H]{=}\frac{(m_m+1)((m_s+1)}{(m_m ms)}\ {\Omega_0}^2$
Here $m_m$ is the Nakagami-m multi-path fading parameter for $\frac{1}{2} < m_m < \infty$. Lower the estimations of $m_m$ relating to the terrible channel condition. Furthermore, the request of Gamma work $m_s$ permits, changing the lognormal shadowing to Gaussian distribution. Consequently, the Gamma dissemination can be utilized to demonstrate distinctive instances of multipath blurring and shadowing by utilizing the correlative estimations of $m_m$ and $m_s$ separately. In equation 1 for H > 0, $m_s$>0,$m_m$>0 and $\Omega_0$=1. As this point dependent on the transmission demonstrate we can infer the mystery rate of m with SU n's agreeable transferring R(m(n))^C. It is very well may be communicated as lower the estimations of $m_m$ comparing to the awful channel condition. Likewise, the request of Gamma work $m_s$ permits, differing the Probability Density Function (PDF) of shadowing from lognormal to Gaussian permitting flexibleness. Henceforth, the Gamma circulation can be utilized to display diverse instances of multipath blurring and shadowing by utilizing the integral estimations of m_m and $m_s$ separately [49].

$$\boldsymbol{R^C_{m(n)} = \propto_n [R^C_{m,b}(n) - \max_{k\varepsilon\epsilon} (R^C_{m,k}(n))]} \qquad (2)$$

### B. Proposed Method

In consistent direct correspondence somewhere in the range of P1 and P2, every transmitter utilizes a transmit power Pt to communicate with the collector for a length T accomplishing an information transmission rate. During the communication establishment [50] the cognitive radio has t [24] limited authorization to approach for the range of communication. The total time for the direct and bi-directional communication is 2T.

### C. DSL with honest CRs

The beamforming dynamic range leasing approach of communication is valuable for a length TL. This time is separated into three stages. 1) Broadcast stage during time t1 where both amid P1, P2 together communicate the information among themselves with transfer rate of CBD, 2) De-commotion and pillar shape (CBD) stage for time t2 amid which the auxiliary transfers are separated into two gatherings every one of which denoises and shaft frames the coded information near its adjacent essential beneficiary P1 or P2 at a rate CBF , 3)t3 is the length of recuperation stage, where the range is intentionally accessible to the Cognitive radio transmission . Demonstrates the best possible task of Dynamic Spectrum Leasing. For two stages Dynamic range renting based direct communication, the viable normal DSL limit CDSL is then given as.

$$\mathbf{C_{DSL} = min\ (C_{BD}, C_{BF})} \tag{3}$$

The effectiveness of the essential and the auxiliary system clearly rely upon the division of time between t1, t2 and t3. The ideal time-shares t1, t2, t3 for getting maximum throughput obtained by Nash based division. The important part in the node is paving way for secure communication by amplifying the time t1,t2 to exchange the information among the participating auxiliary nodes. The total leasing time is given by

$$\mathbf{t_1 + t_2 + t_3 = T_L.} \tag{4}$$

The Cognitive Radio relays network in the receiving station consist of both P1 and P2 data for the simultaneous transmission of time $t_1$.This is said to be Physical [23] Layer Network Coding (PNC).

$$\mathbf{y_i} = \sqrt{\mathbf{p_t l(r_{1i}) H_{1i} s_1}} + \sqrt{\mathbf{p_t q(r_{2i}) H_{2i} s_2 + n_i}} \tag{5}$$

$\sqrt{H_{xi}}$ and q $(r_{xi})$ *are* Gamma distributed channel,
$n_i$ are AWGN the Receiver.

**ALGORITHM:**
(DAF-DSL Frame work)
Determine-and-Price $(\mathbf{P_{tr}}, t, \mathbf{S_{tr}}, \boldsymbol{\theta}, \widehat{\mathbf{U}}, \widehat{\mathbf{V}})$
**Input:** auctioning Primary user $\mathbf{P_{tr}}$, auctioning Secondary user $\mathbf{S_{tr}}$,
Auctioned result $\boldsymbol{\theta}$, ask value $\widehat{\mathbf{U}}$ and bid value $\widehat{\mathbf{V}}$**;**
**Output**: Primary winner $\mathbf{P_w}$, secondary winner $\mathbf{S_w}$ ;
$\mathbf{P_{wi} = S_{wi} = \phi;}$
Arrange the primary users $\mathbf{P_{tr}}$ in ascending sequence $\widehat{U}_m$;
Arrange the secondary users $\mathbf{S_{tr}}$ in descending sequence $\widehat{V}_n^{\theta(n)}$;
k = arg max $(\widehat{V}^{\theta}_{<n>})$
y = arg max $(\widehat{U}\theta_{<m>})$
$P_w{}^1$=TOP $(P_L,\ k-1)$;
$S_w{}^1$= TOP$(S_O$, y-1);
$T_t$= $t_{DSL}$ $(P_w{}^1, S_w{}^1)$
Update k and y
$P_w{}^2$=TOP $(P_t,\ x-1)$
$S_w{}^2$= TOP $(S_t$, k-1)
$T_{t'}$= $t'_{DSL}$ $(P_w{}^2, S_w{}^2)$
For all the m $\in \mathbf{P_w}^1, \mathbf{S_w}^1$do
If $\boldsymbol{\theta}(\mathbf{n}) \notin \mathbf{P_w}^1$**then**
$\mathbf{S_w}^1$=$\mathbf{S_w}^1\backslash\{\mathbf{n}\}$**;**
If $\theta^{-1}$(m) $\notin \mathbf{S_w}^1$ **then**
$\mathbf{P_w}^1 = \mathbf{P_w}^1\{\mathbf{m}\}$;
If $|\mathbf{P_w}^1| \geq \mathbf{P_w}^2$ **then choose the winner of auction**
$\mathbf{P_w} = \mathbf{P_w}^1, \mathbf{S_w} = \mathbf{S_w}^1.$

### D. Selfish Cognitive Radio Network

A selfish CRN node will get benefit during the auction by utilizing the maximum spectrum. Notwithstanding, actually, some narrow minded nodes should need to build their focal points by not participating with the essential amid the second powerful range renting period of de-noising and beam-forming. Fig 2 demonstrates the performance of selfish user to compete with other nodes in the network during time duration t2.

## 4. Terminologies in Crns

**1) Determination of Selfish Nodes:**
There are numerous approaches to distinguish the selfish user who disturbs the nodes in the network. A approach for accomplishing each CR user to perform in the dynamic leasing [20] process needs to send a description alerts in a predefined way. In the next stage of DSL the information to distinguish the malicious nodes from the opportunistic nodes is identified by DAF-DSL scheme. Another technique to recognize the malicious nodes is to utilize the auctioned result. The throughput is performed by utilizing forbidden codes has been proposed and it is exceedingly effective. For our work, the progression of exchange of terms before a dynamic range renting correspondingly is anything but difficult to utilize any of the made reference to ways to deal with distinguish the malicious nodes.

**2) Transfer Function of malicious nodes:**
The malicious nodes CRs gets privelege to transmit amidst other users in the network. In addition, according to the DSL understanding, these nodes additionally acknowledge transmission amid the compensation time.
**3) Capacity of DSL**
With the end goal to contrast the proposed range renting plan and consistent communication execution, [21] it is imperative to restore the immediate two-route communication somewhere in the range of primary user 1 and Primary user 2. The diagnostic information transmission rate R when Primary user 1 sends its message to primary user 2 is given by

$$\mathbf{R = \log_2(1 + \gamma)\ (bits/sec)} \tag{6}$$

Where $\boldsymbol{\gamma} = \frac{\mathbf{p_t H_p l(r_p)}}{\boldsymbol{\sigma^2}}$.
$H_p$ is the channel control gain among the user 1 and 2, $P_t$ is the transmit power and $r_p$ gives the distance dependent upon the path loss between the nodes. The separation between the two nodes are same and the channel is corresponding, expected that the communication rate from P1 and P2 is the equivalent as the transmission rate from P2 to P1. θ is the result of auction. The biggest rate of transmission R with the end goal is that the maximum likelihood factor on this specific connection is fewer than the ρ utilizing the channel power gain as Gamma distribution of the ρ-blackout probability is given by,

$$\mathbf{P_{out=P_r}\{\gamma < \gamma^{th}\} < \rho} \tag{7}$$

Here $\gamma^{th}$ is the threshold value of Signal to Noise Ratio above than the value $P_{out}$. By applying the Gamma distribution, the progress probability is expressed as Outage probability **ρ.**

$$\frac{\mathbf{Q}\left(\mathbf{k}\frac{\boldsymbol{\gamma}^{\mathbf{th}}\boldsymbol{\sigma}^{\mathbf{2}}}{\mathbf{l}(\boldsymbol{\gamma}_{\mathbf{p}})\mathbf{pt}}\boldsymbol{\theta}_0^{-1}\right)}{\boldsymbol{\Gamma}(\mathbf{k})} = \boldsymbol{\rho}, \tag{8}$$

Where $\frac{\mathbf{Q}(\mathbf{k}\frac{\mathbf{x}}{\boldsymbol{\theta}_0})}{\boldsymbol{\Gamma}(\mathbf{k})}$ is the lower order gamma distribution function.

By applying, the inverse Gamma distribution function $\Gamma^{-1}$ evaluated using any advanced simulating tools. The outage capacity $C_{out}$ is defined by,

$$\mathbf{C_{out}} = \left(\mathbf{1} + \frac{\mathbf{p_t l(r_p)}}{\boldsymbol{\sigma^2}}\, \boldsymbol{\Gamma^{-1}}(\boldsymbol{\rho}, \mathbf{k}, \boldsymbol{\theta_0})\right), \qquad \textbf{(9)}$$

**4. Maximum attainable Data Rate:**
The maximum attainable data rate in terms of bits transmitted by secondary user is expressed as,

$$\mathbf{R_a} = \frac{1}{B}\int_0^{\infty} \log\left(1+\gamma\right) f_{\gamma e2e}(\gamma)\, d\gamma \qquad \textbf{(10)}$$

$$\mathbf{R_a} = \frac{1}{\mathbf{B \ln 2}} \exp\left(\frac{(\mathbf{K}-1)\sigma^2}{\lambda\eta}\right) \mathbf{E1}\left(\frac{(\mathbf{K}-1)\sigma^2}{\lambda\eta}\right) \qquad \textbf{(11)}$$

Where B is the duration to effectively complete an entire transmission slot taken for a single data transmission from an opportunistic node to its destination.

**5. Leasing Time Duration**
The amount of time required for the network to get the maximum efficiency by increasing the channel capacity defined by the summation of all the three time sequences considered so far. For this reason, we prepare an exchange over the entire duration $t_1$, $t_2$ and $t_3$ to get the leasing time $t_{DSL}$ sequence for the secondary users to communicate in the spectral bands for the stipulated time duration.

$$\mathbf{t_{DSL}} = \mathbf{Max}(\log(\mathbf{t_1} - \mathbf{t_{01}}) + \log(\mathbf{t_2} - \mathbf{t_{02}}) + \log(\mathbf{t_3} - \mathbf{t_{03}})) \qquad \textbf{(12)}$$

**6. Spectrum Sensing Data Falsification (SSDF) Attacks**
In the presence of a node in the auction, it is distinguished and examined utilizing the recognition strategy with high accuracy among the more drawn out scenario. The authentic recreation gives more explanatory outcomes proof to our evidence. There are two forms of SSDF attacks, similar and collaborative SSDF attacks, which break down their effects on the precision of synergistic spectrum detecting [22].

## 5. Simulation Results

We have portioned the execution of DSL by making genuine nodes i.e., $\varphi = 0$. At this instance, we check down the narrow-minded conduct of some CR hubs impacts the aggregate execution of the DSL framework. Fig. 1 demonstrates that expanding $\varphi$ pretty much enhances CBD amid stage I. from this issue we dissected that the diminishing in the immediate number of CR transfers that really get the essential information to hand-off can be viewed as later. From this number declines, we can discover generally the separation of any essential hub to the extraordinary genuine CR hand-off reductions. The narrow minded conduct for the most part decreases the limit in stage II, from fig 1 the CR nodes performs egotistically. Such decrease can prompt close decrease in the nature of administration of transferring concurred by the CRs primary concern in the essential system to obtain misfortune in the ordinary CBF. The essential permits to renting time t3 on the obliging that all CRs genuinely participate. The malicious conduct not just lessens the information rate of transferring of the essential information yet in addition impact more noteworthy rewards identified with the essential system.

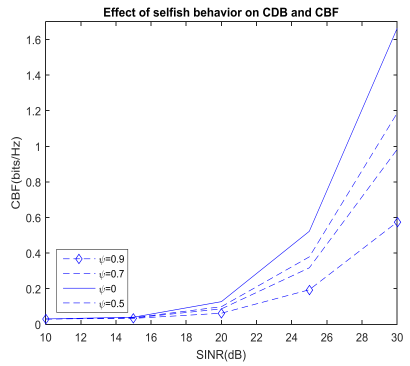

**Fig 1:** Impact of selfishness on Beamforming.

Fig. 2 analyses the effect of selfishness on the beamforming duration time $t_1$ when the dynamic leasing results in the maximal gain. It is obvious that the effect of the malicious activity in Cognitive Radio Network minimizes the selfishness among the secondary users in the network density. Fig. 2 shows the impact of the Time Bandwidth Product ratio implies the selfishness by improving the value of $\varphi$ in the considered network. It is obvious that the malicious activities of the selfish nodes behavior in the network varied from $\varphi$ = 0 to 0.9 for the different leasing time durations $t_{DSL}$ is plotted in the following figure.

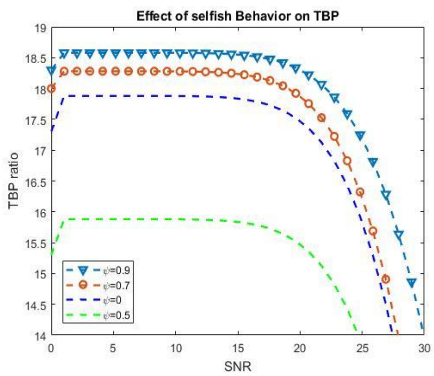

**Fig 2:** Impact of selfishness on Time Bandwidth Product.

Fig 3. Shows that the increase in the number of opportunistic users in spectrum band considered the throughput improves considerably in terms of the secrecy rates of the communication in the auction and the transmission phase. Here we compared both DAF-DSL scheme and baseline transmission without considering the auction in the considered area. The throughput improves for the increased number of Secondary Users and the selfish users. The results show that the proposed scheme provides the maximum throughput than the baseline approach.

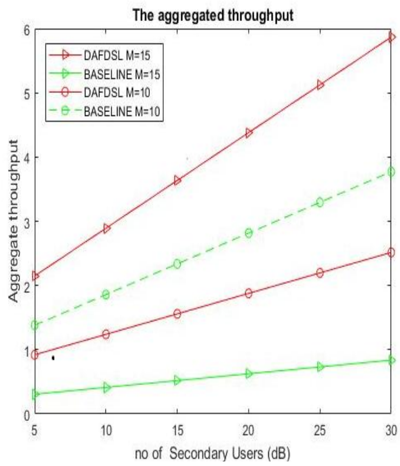

**Fig 3:** Throughput data rate versus SUs.

Fig 4: shows the Selfish SU detection rate vs. Malicious Density SU density. We are detecting SUs selfish with the help of malicious [32] behavior for different number of users in the band of spectrum.

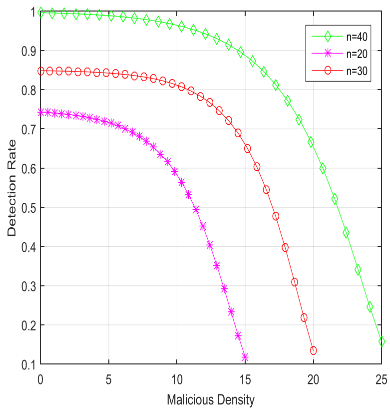


**Fig 4:** Selfish SU detection rate vs. Malicious Density.

## 6. Conclusions':

This work investigate the combined efforts of the Double auction framework and the Dynamic Spectrum Leasing (DAFDSL) scheme implemented to improve the spectrum utilization for increased number of the legitimate, opportunistic and the selfish/malicious users in the network. The auction results shows that in Time Bandwidth Product ratio plot the dynamic leasing of spectrum for the opportunistic users improves significantly compared to the licensed and secondary user communication in the baseline scheme. This work shows significant improvement in the throughput demands in Cognitive communication with auction framework. The DAF-DSL scheme outperforms the normal DSL and auction schemes in terms of improved spectral utilization for the users participating in the auction. The performance of the existing baseline schemes degrades for the increase in malicious nodes in the network. In future, the performance of this proposed algorithm under further increased number of malicious users in network to be studied to provide further secure communication.

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