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A NOVEL COALITION GAME THEORY BASED RESOURCE ALLOCATION AND SELFISH ATTACK AVOIDANCE IN COGNITIVE RADIO AD-HOC NETWORKS

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ABSTRACT

Cognitive radio (CR) is an intelligent radio, which is been targeted to exploit the utmost available spectrum holes for unlicensed users by sensing the environment. The arrival of advanced wireless communication devices lead to increase in the demand on the spectrum and the need to improve utilization of vacant spectrum. In the past decade the spectrum sensing and allocation has been the main focus of research rather than the security in cognitive radio. A selfish cognitive radio node is a serious security issue which occupies a part of the resources or full resource which is generally a pre-occupation problem in the multiple channel, and forbids other legitimate cognitive nodes from consuming the resources. This self-centered cognitive radio can critically degrade the performance of the network. So a skillful resource allocation strategy should be adopted to avoid these selfish attacks in the network. The conventional resource allocation approaches in the cognitive network are fully dependent. In this scheme, the coalitional game theory incorporates multiple PU and SU in a pool, in which the PU allow other SU's to make use of its resources in contract or agreement on a timely basis. This scheme adopts efficient resource allocation in a multichannel cooperative system. This proposed system follows the core concept and also supports Shapley value in order to have a non-empty core in the network. The Shapley value equally distributes the payoff throughout the users in the network. It insists that the performance of the proposed scheme has been improved to a near optimum value of 93.7% rather than the performance of the existing COOPON system which figured to only about 74%. By this resource allocation approach, the selfish attacks can be prevented and thereby the efficiency of resource utilization in the network can be considerably increased.

Keywords: *Cognitive Radio, CRAHN, Selfish Attacks, Pool, Coalitional Game Theory, Shapley Value.*

1. INTRODUCTION

1.1 CRN (Cognitive Radio Network)

The significant growth in wireless environment leads to the extreme usage of the spectrum. The static spectrum allocation for licensed users make the utilization of spectrum resources inefficient and the unlicensed bands i.e., ISM bands, are congested due to competing of many wireless applications. To enhance the efficiency of the spectrum, Mitola formulated "Cognitive Radio" in which the unlicensed user can use the spectrum holes of the licensed bands when they are idle without causing interference with primary user or licensed users. Federal Communication Commission (FCC) approved this CRN to overcome the spectrum shortage problems in both licensed and unlicensed bands. CR (Cognitive Radio) is an opportunistic radio that is well known in the wireless communication network.

A CR definition [11] states as, "CR is defined as a radio that can vary its transmitter parameters by means of perception within the environment". In cognitive radio, the two uniqueness [15] like "Cognitive capability and reconfigurability" have been mentioned. Thus, Cognitive radio is an intelligent radio that modifies its internal capabilities or parameters in response to its environment changes and identifies the white spaces for unlicensed user's result in reliable

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communication. Dynamic Spectrum Access (DSA) method is integrated with cognitive radio in order to find the spectrum holes and solve the problems in spectrum inefficiency. Thus, the SU (Secondary User) switches to the new spectrum band when PU (Primary User) signals are detected and avoids interference with PU transmission.

I. F Akyildiz et al [1] describes an overview of cognitive radio network functions as mentioned below,

- Spectrum sensing: Identify the vacant resources and share it without causing interferences with others.
- Spectrum management: It grabs the best available resources to accommodate the customer requirements.
- Spectrum sharing: It provides the spectrum scheduling approach for the existing user in the network.
- Spectrum mobility: It manages the communication requirements for transition.

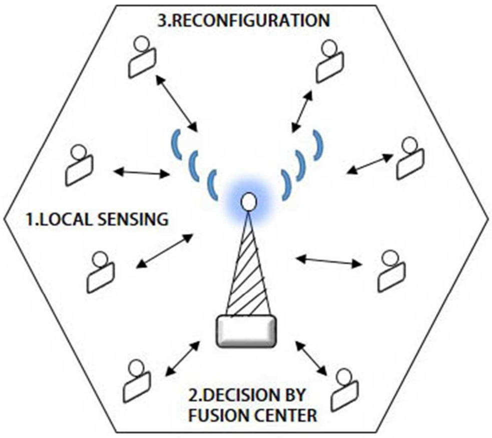

Figure.1. Infrastructure Based CR

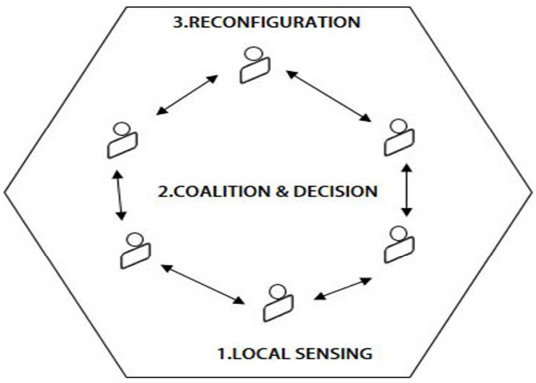

Figure.2.CRAHN

The Cognitive Radio Network architecture (CRN) is classified into infrastructure based CR as shown in Figure 1. Likewise, Cognitive Radio Ad-Hoc Network (CRAHN) is shown in Figure 2. The infrastructure based CR has a base station in which the interfering is avoided and also resource allocations are monitored and controlled. Meanwhile in CRAHN [2], it lacks in the infrastructure, and each CR node communicates with multi-hop, reconfigures itself and responses to its local observations. In order to avoid interference, the information is distributed to the neighbour nodes using cooperate method. This operation would mitigate the scarcity of spectrum usage and results in high efficiency and utilization. In CRAHN, the spectrum management researches are done widely in the area of spectrum sensing, routing protocols, and spectrum allocation. There is a significant lack of interest level towards the security side, which can emerge as a potential issue later. Some SUs in the network will react in a selfish manner, which leads to selfish attacks in the network. It results in the holding of resources by prohibiting other LSU (Legitimate Secondary User) from accessing the spectrum resources. SSU (Selfish Secondary User) should be identified and detected in order to improve the spectrum usage and performance in the network. The selfish attacks may be PU (primary user) emulation attack or a Preoccupation attack. The SSU will send PU signals i.e. Fake PU signals to other SU. Thus, LSU listens to this signal and detects PU which is in action and switches to another channel. The selfish attacks are done either by PU emulation attack or Preoccupation attack.

1.2 Our Contribution

In this paper, the pre-occupation attacks by multiple SSU are prohibited which disrupts many of the LSU's from utilizing the resource, thus a well-practiced resource allocation method is used to prevent these selfish attacks. The coalition game theory and core concept are introduced. The coalition game approach is used for resource allocation in order to avoid selfish attacks. This adapts cooperative communication between the PU and SU in the multi-channel and multi-hop networks are thereby handled to support many relays for SU and PU transmission. The core is non-empty. In this game theory, they pool their resources which is in usage and vacant in the network on a timely slot manner. Shapley value fairly divides the payoff between users. The PU leases the spectrum to SU for its payoff. This results in low energy consumption and increases the

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throughput in the system. The proposed approach supports cooperation between many users and highly reliable transmission.

2. RELATED WORK

The traditional wireless network detecting the selfish attacks is impossible in CR network due to the dynamic nature of CR nodes. Moreover, these CR nodes have unique features and challenges in it. Normally selfish attacks have occurred due to abnormal behaviour like selfishness or any threatening behaviour of CR nodes in the network. One example of this attack is the PU emulation attack [8,14,25], in which the SSU will intimate other LSU by emulating like PU signals. LSU will misconceive that a PU is active. This makes LSU to prohibit the resources and jump to another resource. Another type of network attack is the SSDF (Spectrum Sensing Data Falsification) [21]. Here the disloyal SUs will report false information about spectrum sensing so that a PU is addressed to be present when it is inactive, or to address a PU as inactive, when it is actually active. The combined cooperative game theory and Nash bargaining [5] figures out the interference within the users and progressed to cancel the interference. The Bayesian slotted aloha game model [9] traces the selfish nodes behaviour and the Nash equilibrium hinders the selfish users in the system. With the help of Interference Cancellation(IC) and the best relay selection [10], the cooperation has been enhanced and the interference within the users has been considerably reduced. Chandramani Singh et al [7] illustrated about the equal partition of payoff among the users using grand coalition, which supports core concept and Shapley value thereby maximizing the resource efficiency. The location privacy threats are illustrated [20, 24] and a protocol to overcome these threats has been proposed. Another major threat, intrusion detection system [12] is prevented. The comparative analysis is made with three game grid based resource allocation [19]. It gives a clear idea about the theoretical aspect against the conventional method. The game theory is used to detect the selfish attacks [17, 23] in the system. The spectrum sensing is improved by means of Minimum Sensing Error (MSE) in the multiple cross over cognitive network [16]. Yu-Wei Chan et al [22] describes the payoff problems between the users. Minho Jo et al [18] addresses the problem of pre-occupation by an SSU and is detected by COOPON method. It prevents the occupation of channels, which results in high reliability and performance in the network. Gohila et al [3, 4] describes about the multiple selfish users and described two different approaches to overcome these attacks. Our proposed approach would improve the reliability and spectrum efficiency in the network.

3. COALITIONAL GAME THEORY

3.1 COOPON System

The cognitive radio network aims to make the utilization of the available spectrum in the communication network. The existing system uses COOPON [18] to analyse the selfish user in the network. Normally SU uses CCC (common control channel) knowledge and begins to propagate their channel information to its one hop users. The selfish users can send bogus data to their neighbours in order to pre occupy more resources for their own use. Thus, the legitimate users are prohibited from accessing the channels thereby resulting in inflexibility during resource sharing. The COOPON method mentioned in Figure 3, overcomes this problem by seeking the cooperation of all the one hop users in order to identify whether the selected node is selfish or not. COOPON has advantages like reliability, high performance but lacks in certain conditions e.g., when the SSU multiples, the COOPON method is not applicable.

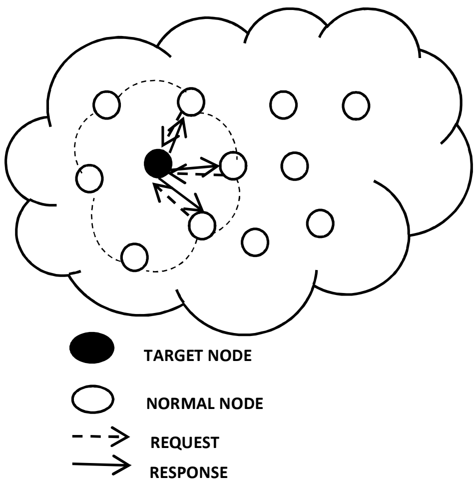

Figure.3. COOPON Method

3.2 Overview of the Proposed System

The proposed system aims to overcome the problem of COOPON by introducing coalition game theory with Shapley value and pool. It illustrates about the collaboration among the users and examines their behaviour in the network. The pre-occupation problem is mainly focused to deliver the flexibility in resource sharing. The approach of coalition game theory is to layout a

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cooperative network in which the players cooperates in all aspects. This develops an efficient and robust cooperation in the communication network.

Example: land owner and workers: Here player 1 is the land owner and workers are the set of players (2….n).The participation in the land work needs both of them to cooperate, otherwise the result will be zero.

The game theory cooperates with every user such as PU and SU who involve in the game or work. Meantime the PU has the highest priority in accessing the channel than SU. In such a way, when that PU demands resources, the SU should return back the resources and jump to other vacant resource. The PU incorporates by dropping their resources and subscribers in a pool. The pool maintains the resource allocation process and the stability of the system is maintained by the core concept, but it lacks by keeping the pool empty. The PU and SU request the resources in the pool and automatically the time is updated, so the request of every user and release of resources are frequently updated in the pool. Within a period of time, the users should access the resources, then leave way for other users and avail a new request, if needed. In coalitional game theory, two sharing solution concept [7], has been stated as follows,

- Shapley value
- Nucleolus

These concepts present a solution to distribute the fair distribution of aggregate payoff among the users. In nucleolus, the sharing is based upon the satisfaction level. When the satisfaction level is high, nucleolus begins its sharing. Even though the satisfaction level is low in Shapley value, it starts its distribution of payoff among the users. The main focus of the system is to have non-empty pool (i.e.) a pool atleast has some resources to satisfy other users, so a Shapley value is adopted here. The Shapley value [7] is as mentioned below.

For any i and $S \subset \mathcal{N}$ such that $i \notin S$, let $\Delta_i(S) = v(S \cup \{i\} - v(S))$. The Shapley value imputation x for which

$$x_i = \frac{1}{n!} \sum_{\cup \in u} \Delta_i(S_i(\cup)) \qquad (1)$$

where, u is the set of all orderings of the set of players, and $S_i(\cup)$ is the set of players preceding i in ordering $\cup$.

Thus, by the concept of pool and Shapley value, the pool is not empty which makes the resource to be available all the time and results in flexibility of resource sharing and selfish behaviour users are precluded in the system. The pre-occupation problem is depicted in Figure 4. The fake information is exchanged between the adjacent users and prevents them from accessing the resources.

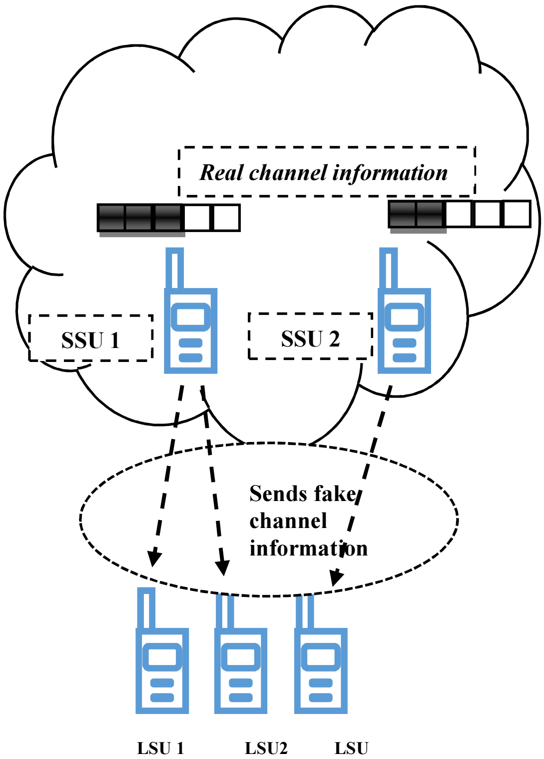

Figure.4. Pre-occupation problem by multiple users

Consider that SSU 1 has 3 channels as allocated and remaining 2 channels which are free, is sensed by the available resources, so that the other LSU will request them. This SSU 1 responses with fake channel information by sending 4 channels as is in usage and prohibits other users from accessing it. Likewise, SSU 2 behaves like SSU 1 to other users. If many selfish users send the fake information, pre-occupation problem arises which will obviously degrade the performance in the network. In order to prevent this, coalitional game theory and Shapley value is adopted. The Shapley value equally divides the average resources payoff to the requesting users and omits the conflicts between the users.

4. PROPOSED SYSTEM DESIGN

The system design depicts about the detailed process flow of the proposed methodology which is

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mentioned in Figure 5. Generally the pattern of the system has some advantage by hindering the activity of the selfish behaviour in the network. This makes the system with good performance and elasticity in resource sharing.

4.1. Node Distribution Phase:

The network set up of 100 nodes with some pre-defined condition such as data rate, protocol, antenna type etc. are specified as mentioned in Table 1. The node distribution phase is further classified into three sub modules,

- Node creation
- Node configuration
- Node deployment

The above classification is described as mentioned below,

4.1.1 Node creation:

Here the nodes are created as per the system condition. Approximately 80 nodes are created. The nodes with priority are assigned in order to differentiate them.

4.1.2 Node configuration:

It describes the specifications for creating a node in the network such as date rate, protocol etc. 80 nodes act as users, with 50 PU and 30 SU and as per condition, the PU should be maximum than SU. The remaining node acts as antenna, base station etc.

4.1.3 Node deployment:

The mentioned nodes are formed as a network in which the resource requisition and acceptance are made. The PU node has higher priority than SU in the network.

4.2. PU/SU Classification Phase:

As illustrated, PU has higher priority than SU in the network. Thus when PU is in active state to access the resources, the SU which holds their resources should return back their sources and jump to another vacant resource. The PU/SU classification phase is further classified as,

- Primary user classification
- Secondary user classification
- Resource description

4.2.1 Primary user classification:

The node with higher frequency remains unique in the network and has more priority in accessing the resources. They are the owners of the resources and PU should coordinate to dump their resources in single space by means of agreement basis.

4.2.2 Secondary user classification:

The nodes have the frequency which is below than the PU and must have the capability to return the resources in order to avoid interference with SU.

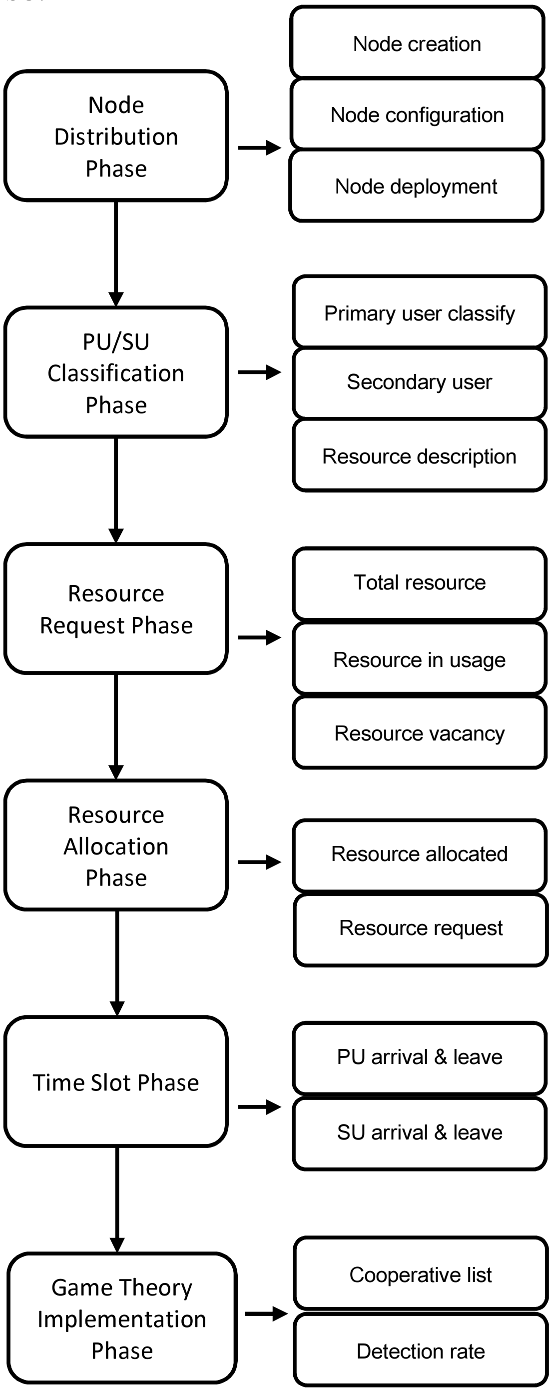

Figure.5. Process Flow Diagram Of Proposed Design

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The SU which grasp the resources for linger time are avoided here by means of introducing accessing time in the system.

4.2.3 Resource description:

This gives a description about the frequently accessed resources and their updating time in the pool. PU drops their resources into the pool for the subscriber's to access them.

4.3. Resource Request Phase:

As the resources and users are dumped in a pool, the cognitive users request the pool for the resource and are automatically updated. Any user can request them. They are further categorized as,

- Total resource
- Resources in usage
- Vacant resource

The resource requests are frequently updated and priority is assigned for the users.

4.3.1 Total resource:

This describes the total resources available in the pool. As the pool handles the resource in an efficient manner, it should not be empty in any condition. Only limited users are allowed to use the resources.

4.3.2 Resources in usage:

The users accessing the channel are recorded in the pool and have the list of resources which is currently allocated and is in usage. When a certain period time is over, the corresponding user should return their channels and make a request to other vacant channels in the pool.

4.3.3 Vacant resource:

The pool must always be a non-empty space, thus it permit the users to access the channel. The vacant resources are updated simultaneously when the user leaves the network.

4.4. Resource Allocation Phase:

The resources are allocated based on the priority and depicts that the allocation is based on the Shapley value in which the user accepts with low satisfaction of accessing the resources. Eventhough the resources are low than the value which is predefined, the user must satisfy the pool to be non-empty in order to avoid selfish attacks. The resource allocation is further classified as,

- Resource allocated list
- Resource request priority

These are described as follows,

4.4.1 Resource allocated list:

The allocated resources with corresponding users are examined to clearly point the user holding the resources for a longer time. The cognitive user using the channel with respect to time is noted. Each node has a unique distribution of resources and holds a history of overused resources. This gives a clear cut description about the node work. Shapley value is calculated for the individual node.

4.4.2 Resource request priority:

The resources are allocated based on the priority made by the system. The SU is blocked when the channel increases, thus minimizing the interference with other users.

4.5. Time Slot Phase:

The pool updates every action about the users and records their time interval. The handoff between the users are demonstrated and the gap between the time intervals specifies the resource usage in the network. The two sub phases are,

- PU arrival and leave time
- SU arrival and leave time

The time slot makes the resource sharing in an efficient manner thus, the users with allocation are recorded simultaneously.

4.5.1 PU arrival and leave time:

The primary users are the owner of the resources who lend their resources to other SU's for earning profit. Here PU handoff and usage of resources with respect to time is experimented.

4.5.2 SU arrival and leave time:

The secondary user request, usage, and leave time are depicted here.

4.6. Coalitional Game Theory Implementation:

The concept of coalition game theory is to incorporate every user to work in a complete manner. Here, it aims to avoid the attacks done by SSU, thereby delivering the system with good performance and reliability. It is sub-divided into

- Cooperative list
- Detection rate

4.6.1 Cooperative list:

It consists of a list of users who are in active state to join the environment. Thus, it combines every user to examine their behaviour.

4.6.2 Detection rate:

The detection rate of the proposed approach is compared with the existing system. Finally it predicts with the improvement in performance and flexibility in resource sharing than the existing system [18].

5. IMPLEMENTATION AND RESULT

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Generally, the pre-occupation problems are alarming security issues in the cognitive radio network. The environment is set with a RAM of 4GB, i5 processor, hard disk of 500GB and simulated in matlab. The Omni type antenna is employed here and it is a wireless antenna which is basically used in cellular telephones for scattering the radio frequency electromagnetic waves propagating in the balanced horizontal direction. During the propagation of signals over a long distance, fading of signals arises which is a major weakness in the network. The addition of Rayleigh fading can overcome the multipath fading problem. The Rayleigh [13] is given by,

$$\mathcal{P}(\mathcal{Z}) = \frac{z}{\sigma^2} e^{\frac{-z^2}{2\sigma^2}} \qquad (2)$$

where,

σ^2 is the variance and $\mathcal{Z}$ is the circular symmetric Gaussian random variable such that, $\mathcal{Z} = X + jY$.

The modulation is done by QPSK (Quadrature Phase Shift Keying) and has an advantage of doubling the data rate and encoding of two bits per symbol. The equation of QPSK [6] is

$$S_n(t)=\sqrt{\frac{E_s}{T_s}}\cos(2\pi f_c t+(2n-1)\frac{\pi}{4}) \qquad (3)$$

where,

E_s= Energy-per-symbol

T_s = Symbol duration

f_c = frequency of carrier wave

The proposed system overcomes the COOPON flaw by means of coalitional game theory approach. The experiment is accomplished with minimum SU and maximum PU. The bandwidth range of around 180-300 ω is demonstrated. The angular frequency **ω** is given by

$$\omega = 2\pi/T = 2\pi f \qquad (4)$$

where, ω is the angular frequency, T is the time, f is the frequency (Hertz). The frequency is taken within a range of 0.1Hz to 0.8Hz. The frequency is defined as the complete cycles per second. We observed with 50 PU and 30 SU or CU (Cognitive User).

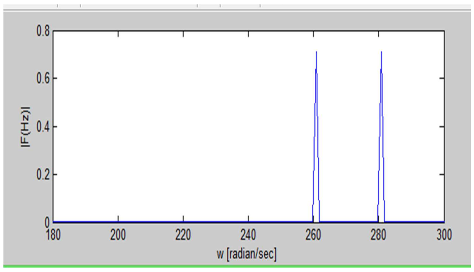

Figure.6. primary user identification

In Figure 6, the high peaks describe the PU users and in Figure 7, the peak describes the SU users. Thus, the classification of users is accomplished. The spectrum band ranges between 180 and 300. The high peak with high frequency of 0.7Hz in Figure 6 shows that PU utilizes the spectrum resources in a high range and the vacant place near the peak denotes the white space in the network. The detailed parameter is as shown in Table 1.

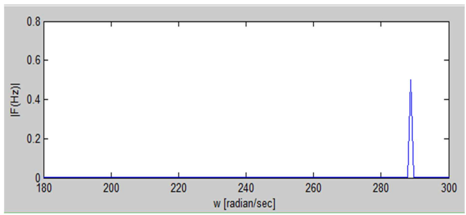

Figure.7. secondary user identification

These PUs have higher priority in accessing their resources than the secondary users. The secondary user in Figure 7 utilizes the vacant resources when PU resource is in idle state. Thus, the major classifications are made, as stated in section 4.

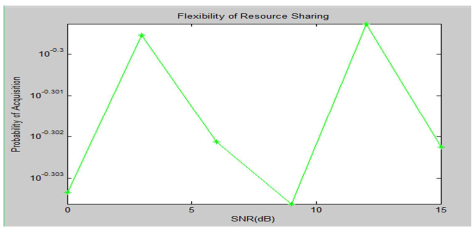

Figure.8.shapley values estimation

As shown in Figure 8, the Shapley value is calculated for the respected channels. Fairly divide the payoff of resources among the users. It depicts the channel is dynamically taken in the range of 10 and experiment it to check with possibility of more than 10 criteria, to prove the system to be dynamic. The resource allocation with respect to SNR rate is

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illustrated. The SNR compares the signal to noise ratio in the system and is measured in decibels.

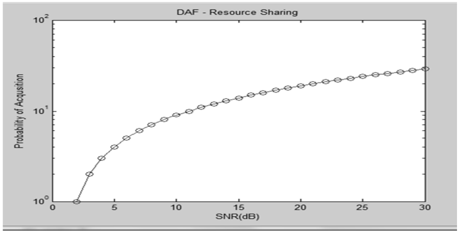

Figure.9. Represent the Resource sharing With Given Timing Information

Figure 9 shows the overall flexibility of resource sharing at a given time. It records the entire request and gives its access at given time to avoid collisions with others. This also prevents the interference with PU. Meanwhile all the users cooperate to have a flexible resource sharing in the system. The fundamental part of the system is to have a non-empty core. The spectrum should be updated frequently about who is currently using the resources and their time limit to release the resources. In order to have a stable non-empty core, Shapley value is adopted here to fairly divide the aggregate resource among users. The Shapley value estimates the payoff for different cognitive users.

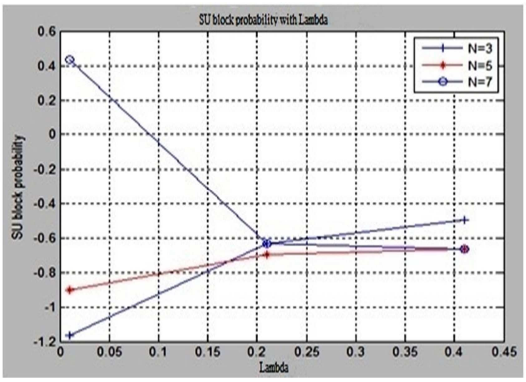

Figure.10. SU's blocking probability

Figure 10 presents the number of SUs blocked to the number of resources available with the system. By considering the threshold value of lambda as 0.4, when the data channels are increased, the blocking property of SU increases simultaneously which results in minimum interference with PU. The channel 3, 5, 7 are demonstrated and the channel 7 has positive blocking value such that interference with PU is prevented. But channel 3 has least blocking than channel 5.

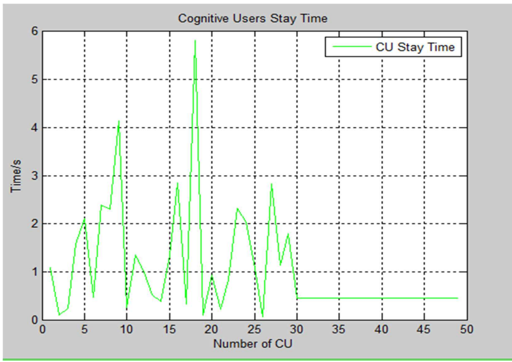

Figure.11. Cognitive Users Stay Time

Figure 11 detects the cognitive user's resource access by estimating their stay time. The one which have high peaks have used the resources for long period. As the number of cognitive users increase more than 30, the CU become idle in using the resources. The constant line after 30 user in Figure 12 is meant with the condition of 30 SU.

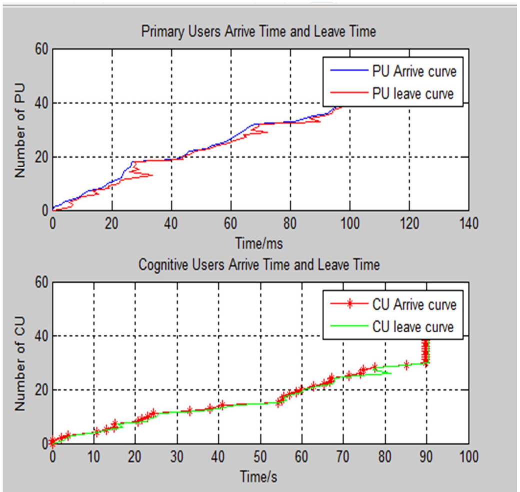

Figure.12. PU and SU arrival and leave time

Figure 12 shows the overall users such as the cognitive user PU arrival and cognitive user leave time are updated in the spectrum pool. The gap between the arrival and release curve shows the user who accesses the resources efficiently in the pool. The presence of spectrum pool holds all the resources within it and gives access to all the users. In CU graph, the users above 30 are requested and leave the system at once. It thus, shows the same condition as mentioned in Figure 12. This results in the efficient communication and avoidance of selfish attacks when the particular node holding the resources for a longer time and again requests for extra resources.

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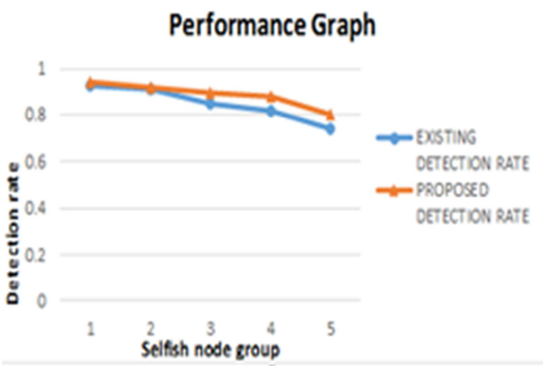

Figure.13. Performance graph

Figure 13 shows the performance of the designed system to that of the available users already designed in the system. When the selfish node group increases, the detection rate is decreased in the existing approach. The existing system COOPON [18] is compared and examined for their performances. Using coalition game theory and Shapley value approach the detection rate of the selfish nodes are increased independent of the number of selfish node groups. Since the detection rate is increased the selfish attacks are easily detected and can be prevented. Thus, the system performance is not degraded because of the selfish nodes. It shows that the proposed system is better than that of COOPON system in terms of performance.

Table 1: Simulation Environment

Parameter	Value
Antenna type	Omni antenna
Bandwidth Range	180-300
Channel type	Wireless channel
Data channel	10
Data rate	3 Mbps
MAC protocol	IEEE 802.11
Modulation	100 nodes
Network Interface Type	Phy/wireless Phy
Network Layer	LL
Number of PU's	50
Network size	100 nodes
Number of SU's	30

6. CONCLUSION

The existing system has some limitations, such as performance and resource sharing issue, when the selfish users are dramatically increasing in the multiple channels network. In the proposed approach, selfish attacks by the multiple channels are avoided by introducing coalition game theory and Shapley value. The core idea is adapted and the use of Shapley value is to equally divide the payoff among the flexible cooperative users which results in keeping the resource pool non-empty and periodically updated. Meanwhile the users are allocated on a timely basis so that the interferences are prevented in the system. It points out the performance of this approach yields 93.7% which is very commendable and is preferable than the existing system with a performance of 74%. This proposed methodology will give a high degree accuracy of detection and moreover will improve the resource allocation in the multiple channels. The perceived limitation in this approach is basically, as the number of users increase in coalition formation, it may lead to overcrowding for accessing the resources and may result in delay in accessing the resources. This may result in the allocation time to be high. The future scope of the proposed methodology is to mainly reduce these perceived limits in the upcoming research papers.

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