Journal of Theoretical and Applied Information Technology
20th March 2015. Vol.73 No.2

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

GROUP FORMATION SCHEME OF CELLS FOR BETTER SPECTRUM EFFICIENCY IN COGNITIVE RADIO NETWORK

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ABSTRACT

A network is an interconnection of different users where different users exchange information with each other using transmitters and receivers. When the information are need to be transmitted automatically then in such cases cognitive radio network is used. The transmitters in the cognitive networks are signaled such that they can automatically detect the available channels and pass signals through them [1]. In such a situation availability of channels plays the important role. As channels are generally limited so they need to be shared among the participating users. The users who own channels of their own are named as Licensed Users (LU), and those does not own channels of their own, need to use channels owned by the licensed users are called Unlicensed users (UU). The existing system tells about the contents of information circulated in the network while the proposed system is all about transferring and gathering information in the network. The cells undergo a game called groups formation where they switch from one group to another in search of available channels.
Keywords: *Cognitive radio Network, Licensed users, unlicensed users, Group formation.*

1. INTRODUCTION

The Channel is a logical connection between a sender and a receiver which conveys information from one or several senders to one or several receivers [2]. We have considered a cognitive network with two types of users. They are Licensed Users (LU) and Unlicensed Users (UU) in each cell in the network. Since the LUs are already registered with channels, so they can send any time or receive signals using their channels. But this is not the case in that of the UUs. The UUs use the same channels which are already assigned to the LUs. So they need to wait till the LUs are done with their transmission. Each cell in the network are responsible for a certain number of UUs. The cells are the media which tells the UUs about the status of the channels belonging to the LUs. For the proper use of the channels by the UUs during the absence of the LUs, the cells should keep an account of the status of almost all the LUs so that it can provide better service to its UUs. But each cell have knowledge of only limited number of LUs.

Our main approach in this paper is to enhance the knowledge of the cells regarding a large number of LUs so that they can provide maximum information to their following UUs. So our proposed algorithm plays a major role, where each and every cell shares the information of each other's LUs by entering into different groups. Thus, the proposed algorithm allows the cells to form different groups and obtain a decision making capacity.

The other sub-sections of the presented manuscript are as follows: The second section describes about the literature survey, followed by proposed system in the third section, including system model, cells forming groups and its algorithm, fourth displays the results and finally conclusion is discussed in section five.

2. LITERATURE SURVEY:

In August 2009, Hamdi, K,Wei Zhang, Letaief, K., in their paper "Opportunistic spectrum sharing in cognitive MIMO wireless networks," discussed about sharing of spectrum among different users in the network. They showed that spectrum sharing approach can be extended to the multiple input/ multiple-output (MIMO) cases also. Their work has reduced the complexity to some extent.

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ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

In Dec. 2012, Hanqing Wen, Tao Huang, in their paper "Signal spectrum estimation of parameter model approach based on MATLAB," discussed about Parameter model methods of spectrum estimation for the users in the network. Frequency, resolution all these parameters of the channel has been discussed in this paper. They came to a conclusion that the estimation performance increases as sampling number increases. But their work didn't concentrated on enhancing the availability of channels for the users in the network.

In May 2009, M. Filo, A. Hossain, A. R. Biswas, and R. Piesiewicz, in their paper "Cognitive pilot channel: Enabler for radio systems coexistence," discussed about the activation of controlled pilot channel which allows the contents to be passed from and to the users in the cognitive network. In this paper they developed a generic scheme to achieve better coexistence between UWB and WIMAX through enhancing existing mitigation techniques.

In Apr. 2007, J. Perez-Romero, O. Salient, R. Agusti, and L. Giupponi, in the paper "A novel on demand cognitive pilot channel enabling dynamic spectrum allocation," addressed the implementation of the cognitive pilot channel (CPC), in wireless networks as a solution to assist cognitive terminals. This paper describes the operation of the CPC and the different approaches existing in the literature depending on how it is mapped onto specific radio resources. Then, it focuses on the implementation of the CPC information delivery and proposes the use of an on-demand CPC, which requires a significantly lower bit rate than the broadcast approach to achieve similar performance.

3. PROPOSED SYSTEM:

3.1 System Model

Let us consider a wireless cellular network M of a set of C cells. Each cell covers a predefined geographical area. The cell set C consisting of c number of cells can be defined as

$$C = \{C_1, C_2, \ldots C_c\} \quad (1)$$

The cellular network provides its network services to a set of licensed users L and Unlicensed users U. The licensed users transmit data or consume the offered services over the pre allocated channels. The licensed users are assumed to be mobile and are distributed randomly throughout the network M. The licensed users can be defined as

$$L = \{L_1, L_2, \ldots L_l\} \quad (2)$$

where l is the total number of licensed users.

The unlicensed users U are randomly distributed in each cell $c \in C$ and is defined as

$$U = \{U_1, U_2, \ldots U_c\} \quad (3)$$

where $\forall\, x \in c: U_x = \{u_1, u_2 .. u_u\}$ represents the u number of unlicensed users in the x^{th} cell.

From [3, 4],it is found that the UUs delay in learning the arrangement and this results in negative performance.

The channels available in the network are pre allocated to the licensed users (LU). Each cell $c \in C$ helps the unlicensed users (UU) to make use of the channels only when the LUs are done with the transmission using their channels. Each cell $c \in C$ is responsible for only a limited number of LUs, so each cell $c \in C$ can gather information regarding the status of only a few LUs. The cells in order to find the status of the LUs use energy detectors. The network is shown in [5-6].The probability of m under the two hypotheses to have central and non-central chi-square distributions under J_0 and J_1may be written as [R9],

$$f_{M|j_0(m)} = \frac{m^{y-1} e^{\frac{-m}{2}}}{\Gamma(y) 2^y} \quad (4)$$

$$f_{M|j_1(m)} = \frac{m^{y-1} e^{\frac{-(m+2\delta m)}{2}}}{\Gamma(y) 2^y} F1\left(y, \frac{y\delta m}{2}\right) \quad (5)$$

where m is the normalized output of the integrator, which serves as the decision statistic. The probability of accuracy in finding the status of LLs by the cells is [9]

$$P^c_{correct} = e^{\frac{-\phi c,l}{2}} \sum_{w=0}^{y-2} \frac{1}{w!}\left(\frac{\phi c,l}{2}\right) + \left(\frac{1+\delta lc}{\delta lc}\right)^{y-1} * \left[e^{\frac{-\phi c,l}{2(1+\delta lc)}} - e^{\frac{-\phi c,l}{2}} \sum_{w=0}^{y-2} \frac{1}{w!}\left(\frac{\phi c,l\delta lc}{2(1+\delta lx)}\right)^w\right] \quad (6)$$

Where w product of time and frequency bandwidth, φcl is the energy detection threshold. The wrong information of the LUs given by cell $c \in C$ over LU channel is given

$$P^c_{fal} l = \frac{\Gamma\left(y, \frac{\varphi c,l}{2}\right)}{\Gamma(y)} \quad (7)$$

Where $\Gamma(.,.)$the function is obtained by allowing the lower or upper limit of integration to vary, $\Gamma(.)$ is the gamma function. Since each cell knows only about certain number of LUs, so they don't have the knowledge regarding the availability and unavailability of all the licensed users distributed randomly in the full geographical area. For proper accuracy of the service provided to the UUs, each

Journal of Theoretical and Applied Information Technology
20th March 2015. Vol.73 No.2

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

cell should know the status of all the LUs all over the cellular network. So to derive the unavailability of all the LUs holding the channels, each cell need to intimate with all other remaining cells leading other LUs. It's the personal decision of each and every cell whether to share the information of their respective LUs with other cells or not. In a network where no cell intimates with any other cell is called a non-cooperative network. So when the cells are not in grouping the serviceability each individual cells can provide is

$$V(c) = \sum_{l\epsilon Lc}\sum_{x=1}^{Uc}(1-p_{fal}^{c},l)\beta_{l\rho_{xc}} - E_l(1-p_{correct}^{c},l)1-\beta_l)(P_{lq_l}-P_{lq_l}^{x})] \quad (8)$$

$$\rho_{xc} = exp\left(\frac{-SNR_T}{\delta_{xc}}\right) \quad (9)$$

$$\delta_{xc} = \frac{P_{gzxc}}{\sigma^2} \quad (10)$$

Where Uc the number of UUs served by cell $c \in C$. Due to the interference caused by the unlicensed user, the penalty factor is El. Sometimes the cell gives wrong information regarding the unavailability of LU, as a result of which the UUs take the channel to be free and transmits their information, but the information gets missed. The missing probability is indicated by $P_{mis,l}^{c}(1-p_{correct}^{c},l)$. Further, $(P_{lq_l}-P_{lq_l}^{x})$ decrease in positive transmission [10].

ρ_{xc} is the possibility of positive transfer between cell and UU. δ_{xc} is the average of the SNR received from unlicensed user by the cell $c \in C$, and P_x is the received power from UU x, z_{xc} is the channel gain between UU x and cell $c \in C$. For improving the potential utility the cells must provide maximum accurate information regarding the unavailability of the LUs i.e. the probability of accuracy should be maximum. So for that all the cells need to develop their knowledge of the status of the LUs belonging to other cells also. The cells need to coordinate among themselves thus forming groups so that they can provide better channel selection for the UUs.

3.2 Cells Forming Groups

Cells can provide limited service to its UUs, because a single cell is responsible only for a small number of LUs $l_c \in L$. So in order to provide highly accurate information regarding the channel availability the cells need to learn the statistics of all the LUs .So there is a need for cells to cooperate with each other and form a group to share the information of all the LUs.

We have considered two groups Z and M. If the cells of Z forms a group with M, then the cells of both the groups can share the information of their known LUs. After forming the groups, the number of LUs known by a cell $c \in Z$ is given by

$$L_z = D_{x\in Z}L_x \quad (11)$$

Where L_z is the LUs known by cell x of groups R. So the availability of a channel learnt by a cell c from another cell x in the same groups is

$$\beta_{cx}^{-l} = \tau_{cx}^{l}\beta_l \quad (12)$$

Where $\tau_{cx}^{l}$is the level of trust the cell c has on the information provided by cell x. When the LU is idle the state is indicated by J_0^l.So during the idle state , the level of trust is

$$\tau_{cx}^{l} = Pro(c = J_0^l | x = J_0^l) = \frac{Pro(c=J_0^l,x=J_0^l)}{Pro(x=J_0^l)} \quad (13)$$

$$Pro((c = J_0^l, x = J_0^l) = (1-P_{wrong,l}^{c})(1-P_{wrong,l}^{x})\beta_l + (1-P_{correct,l}^{c})(1-P_{correct,l}^{x})(1-\beta_l) \quad (14)$$

$$Pro(x = J_0^l) = (1-P_{wrong,l}^{x})\beta_l + (1-P_{correct,l}^{x})(1-\beta_l) \quad (15)$$

Where $Pro(c = J_0^l | x = J_0^l)$ is the probability that cell c tells that a channel is available as claimed by another cell x .

where $(1-P_{correct,l}^{c})$ and $(1-P_{correct,l}^{x})$ are the probabilities of correctly detecting the LUs by the cells c and x . and $(1-P_{wrong,l}^{c})$, $(1-P_{wrong,l}^{x})$ are the probabilities of wrong detection by cell c and x respectively.

Keeping in mind the importance of the trust values given by a cell regarding an LU to another cell ,the cells decide to form groups.The trust value is estimated as in [11] .

For a group, the payoff of any cell $c \epsilon Z$ is given by

$$\psi_c(Z) = \sum_{l\in L_Z}\sum_{x=1}^{U_c}(P_{wrong,l}^{c_l})\beta_{cc_l}^{-l}\rho_{cx} - E_l(1-P_{correct,l}^{c_l})(1-\beta_{cc_l}^{-l})(\rho_{lq_l}-\rho_{lq_l}^{x}) \quad (16)$$

where $\beta_{cc_l}^{-l}$ is the time slot for which the channel is available.

(a) For any channel cell c which is able to detect without any other cell's coordination.

$$c_l = c \quad (17)$$

(b)In case the cell needs to learn from other cells

$$c_l = \underset{x\in Z\setminus\{c\}}{argmax}\left(\sum_{x=1}^{U_c}\left((1-P_{wrong,l}^{c_l})\beta_{cc_l}^{-l}\rho_{xc} - E_l(1-P_{correct,l}^{c_l})(1-\beta_{cc_l}^{-l})(\rho_{lq_l}-\rho_{lq_l}^{x})\right)\right) \quad (18)$$

In the network M multiple number of groups may take place. All these groups need to be designed for devising suitable cooperative strategies for groups formation among the cells. This is defined as Non

Journal of Theoretical and Applied Information Technology
20th March 2015. Vol.73 No.2

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

Transferrable Utility (NTU) in grouping formation[12] and [13].

NTU: $P^{cl}_{correct,l}; Z = 1 - P^{c}_{mis,l}; Z$ (19)

A grouping game (*M, O)* is called non transferrable utility if service abilities of the members cannot be shared.

Within group *S* the reduction in $P^{c}_{fal}l; Z$ as from [3 and 4] is given as

$u(Z) = P^{cl}_{correct,l} - C\left(P^{c}_{fal}l; Z, EZ\right) = \left(1 - P^{c}_{mis,l}; Z\right) - Cost\left(P^{c}_{fal}l; Z, EZ\right)$ (20)

where $P^{c}_{mis,l}; Z$ is the probability of miss for groups Z and $C\left(P^{c}_{fal}l; Z, EZ\right)$ which depends on the $P^{c}_{fal}l; Z$ and on EZ a negative alarm constraint that exceeds *S*.

In a grouping game, the value function and the payoff are two distinct quantities. Given a group Z, the value function $u(Z)$ is the overall serviceability when all cells in Z acts in coordination. For any UU the payoff $\psi_c(Z)$ is the serviceability UU of cell c obtains in ZS. Hence, $\psi_c(Z)$ is the tradeoff between $P^{c}_{mis,l}$;and $P^{c}_{fal}l$ that UU of c obtains being part of of Z.

$u(Z)$, is not divisible among the UUs since it doesn't satisfy the payoff requirement. So it can be said as a grouping (M, O) with NTU,

$Map(Z = \{u(Z) \in \mathbb{S}^{z} | \, u_c(Z) = \psi_c(Z), \forall c \in Z\}$ (21)

A group formation is classified as hedonic in [14 - 16] if and only if:

(i)- Each individual's payoff depends on the others in the same group.

(ii)-The groups try to create new groups from the already existing ones.

A groups can be partitioned as

$\infty = \{Z_{1,\dots} Z_{l},\}$ (22)

which divides the individual cell set M, that is, $\forall\, l \in \{1, \dots, j\}, Zl \subseteq M$ are disjoint groups such that $D^{j}_{i=1} Z_l = M$.

For any cell $c \in M$, a preference relation is such that cell $c \in C$ forms new groups as a result of which the cell can increase its trust value on the other cells of the new group.

$\{Z_l \subseteq M : c \in Z_l Sk\}$ (23)

Thus the cells enter into a process of forming groups after groups leading into groups formation game. The preference relation for casting this game is given by

$Z_1 \le Z_2 <=> f_c(Z_1) \ge f_c(Z_2)$ (24)

Where Z_1 and Z_2 are groups of the network M,where a cell $c \in Z_1$ and $c \in Z_2$ also, and preference function is given by

$$f_c(Z) = \begin{cases} b_c(Z), \; if(b_x(Z) \ge b_x(Z \backslash \{c\}), \\ \forall x \in Z\{c\}\{c\}, \& \;\; j_c\,(Z) \le t_c) or\; (|Z| = 1), \\ -\infty, \; otherwise, \end{cases} \quad (25)$$

where $b_c(Z)$ is the payoff received by cell $c \in C$ in groups Z as, $j_c\,(Z)$ is the list of groups $c \in C$ has visited, and the threshold t_c used by cell c when $j_c\,(Z)$ is maximum.

3.3 Groups Formation Algorithm

Another important process used in the grouping process is the switch rule. In the partition $\infty = \{Z_{1,\dots} Z_{M1},\}$ of network M, a cell c isolates its current group Z_{m1}, and becomes a member of another groups $Z_l \in \infty \cup \{\psi\}$, $Z_l \ne Z_{q1}$, hence forming

$\infty' = \{\infty\{Z_{q1}, Z_l\} \cup Z_l \cup \{c\}\}$ (26)

If and only if

$Z_l \cup \{c\} > Z_{q1}$ (27)

Hence,

$\{Z_{q1}, Z_l\} \rightarrow \{Z_{q1}\{c\}, Z_l \cup \{i\}\}$ (27)

And

$\infty \rightarrow \infty'$

(29)

Switch rule allows the cells to leave any group Z_{q1} and join a new group $, Z_l \in \infty$ as long as $Z_l \cup \{c\} > Z_{q1}$ .Thus, a cell would switch to a new group if it can expect some positive payoff without loss of other cells.

THEOREM:

Thus a single initial network $\infty\, init$ due to group formation results in another network $\infty final$ which consists of different groups of different cells.

Definition:

A partition $\infty = \{Z_{1,\dots} Z_{M1},\}$ is Nash-stable

If

$\forall c \in M$ *s.t.* $c \in Z_{q1}, Z_l \in \infty, Z_l > Z_l \cup \{c\}$ (30)

For all

$Z_l \in \infty \cup \{\psi\}$ (31)

Hence, ∞ will be called Nash-stable, if none of the cells has to move to any other group of cells asking for help to gather information. Hence the cell will be completely independent.

4. RESULTS

We have set up a cognitive network divided into 9 cells with 15 licensed users (LU) and 15 licensed user receiver (LUR) spread all over the 9 cells. There are 9 cells one in each cell, and 72 unlicensed users (UU), 8 in each of the 9 cells in the cognitive network.

Journal of Theoretical and Applied Information Technology
20th March 2015. Vol.73 No.2

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

Initially, each cell $c \in M$ can independently learn and obtain information of $l_c \in L$.Power transmitted by UUs is *10 mW*, and that of LUs is *100 mW*, path loss is $\mu = 3$, SNR to be obtained is 10 dB, the change in noise is $\sigma 2 = -90\, dBm$, the threshold is taken as 5, $\forall c \in M$ and the penalty factor to $E_l = 50, \forall l \in L$. The threshold for energy detection is $\varphi_c; l$ is selected such that $P_{fal}^{c} l; l = 0.05$, $\forall c \in M, l \in L$. The product of time and frequency is set to a common value $y = 5$.

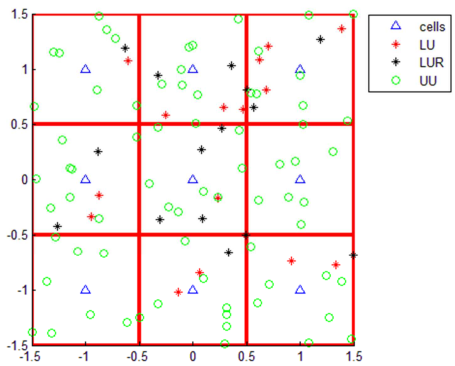

Figure1: A network of proposed algorithm with N = 9 cells, 9 LUs, and 8 UUs per cell.

The cells in figure1 become self-independent, so this network is called Nash-stable. This is because the cells when move from one groups to another expects increase in their payoff.

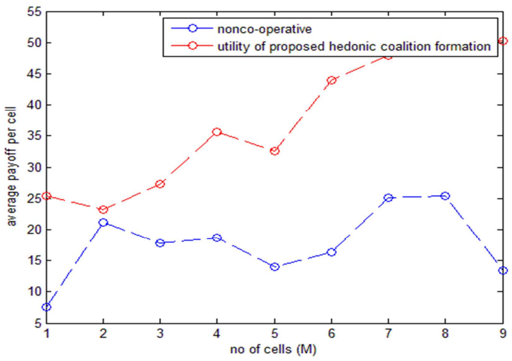

Figure.2: For a network with L = 15 LUs average payoff of each cell wrt. number of cells

Figure2 shows that as cells increase both the non-cooperative and cooperative scheme increases their performance. In our approach the payoff of each cell increases depending upon the capacity of each cell finding higher number of cooperating cells to form more groups, thus more LUs can be shared among the cells.

Figure3 shows that as the number of channels known by each cell increases the utility of each member increases simultaneously. Thus as the cells start obtaining more knowledge regarding the availability of more channels its serviceability increases and are able to provide better service to the UUs.

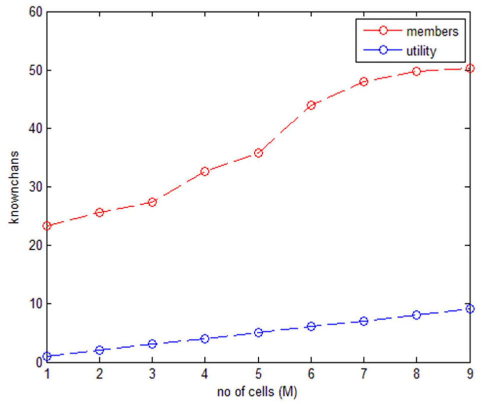

Figure3: The utility of each member w.r.t. to known channels of the cells.

The main ambition of our approach is to ensure the availability of the channels to mainly the unlicensed users (UU). So we have introduced the groups approach so that the cells which are responsible for feeding the UUs with the available channels get in and get out of the groups and share the information of any LU among the other cells. Thus the channels will be used properly by both the LUs and UUs and thus increases the channel spectrum efficiency

5. CONCLUSION

In this paper we have set up an arrangement for allowing all the cells to get connected to each other and share each other's knowledge of the LUs .Each cell is given the right to take the decision to whether to allow or not other users to join its group or not. Thus each cell joins and leaves groups of cells thereby enhancing its utility each time it changes its group. Thus the average pay off of each cell in the proposed scheme is 11% more efficient then non grouping scheme. Future work may focus on reducing the effect of delays in finding the available channels and also

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

allowing several groups of cells to search for the channels in a united forum.

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