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A Collaborative Scheme with Power Adaptation-Equalization and Spectrum Handoff for Mobile Cognitive Radio Networks

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Abstract

The paper proposes a collaborative power adaptation-equalization and also a spectrum handoff scheme for a mobile cognitive radio network. The scheme provides a power adaptation whenever the secondary user is of a mobile category. This is vital to offer a better quality communication to unlicensed users too. The scheme avails the two-ray ground reflection model to take care of the required increase in transmission power. Meanwhile the spectrum handoff scheme's objective is to offer the licensed users, accessibility to channel whenever a request pops up and also ensures that with minimal delay. Henceforth the prime motive of power equalization is to alleviate the harmful interference caused to the adjacent channel users. It is due to an increase in the transmission power. Hence additionally the scheme signals for a spectrum handoff, whenever the transmission power rises above the threshold. Simulation results demonstrate that the throughput of the unlicensed users can be effectively improved by adopting the proposed algorithm. Thus the collaborative power adaptation-equalization and spectrum handoff proves to be an essential part of the anatomy of the mobile Cognitive radio networks.

Key Words: Cognitive radio networks, primary users, secondary users, OFDM and water-fill algorithm.

1. Introduction

The ever increasing population with a flourishing economy, enables it to reach out to the latest technology and makes it much more feasible than what it was in the immediate past. This has led to an exponential rise in demand. However, not all technological systems can afford to take on such an enormous burden. As indicated by the Federal Communication Commission, the majority of the radio range has been dispensed with,leaving a rare range remaining for the new remote gadgets [1]. However, it is found that a significant part of the distributed range lies underutilized due to the approach of sharing altered ranges. For easing the issue of a deficiency of spectrum range, Joseph Mitola III in 1998 proposed cognitive radio system (CRN), it acts as the hero by tackling the deadlock brought about by the static spectrum range task strategy. CR has the innate capacity of savvy utilization of spectra; it can know and can learn, reconfigures itself and adjust it to the radio jolts. Cognitive radios [2] are the main technology for dynamic spectrum access, CRN empowers the unlicensed users (or unauthorized users) to utilize the authorized range meant for the primary users (authorized users) when not being used by them. In any case, they ought to clear the channel on the return of the primary user and proceed with their correspondence on another channel, this usefulness, known as spectrum mobility, guarantees that primary users' correspondence does not get intruded on due to the secondary users and that secondary user keep up a good quality of service [3,5]. One of the difficulties here is to recognize the accessible range groups of the authorized users. For this energy based detection methodology is broadly utilized as a range detecting system due to its low computational complexities and simple execution, it is known as the Opportunistic Spectrum Access (OSA) model.

The Cognitive radio networking systems were considered so far to be stationary with static users; however, this is not true always in the global scenario, the users might be mobile too. In such cases the transmission power of the SUs needs to be monitored to facilitate smooth and uninterrupted communications. Also occasionally when the primary user(PU) who owns the spectrum needs its access, while it is being dynamically used by a SU, then the SUs must switch over from the current channel to some other channel i.e., perform a spectrum handoff.

The power adaptation and spectrum handoff are also dealt with separately in the existing proposals [6]. But this does not suit the anatomy of mobile CRN. Therefore, in this paper, we investigate on how the spectrum mobility can be improved jointly by means of power adaptation-equalization and spectrum handoff schemes [11-12]. The paper is structured as follows. In section II, the network diagram and the proposed power adaptation strategy with its relevant model is narrated. In section III the probability to find an active PU is given. In section IV the analytical model to find SU throughput and test hypothesis to decide for handoff under power-adaptation scheme is enlightened. In section V, the power equalization scheme is demonstrated. In section VI performance evaluation is done. And finally in section VII conclusion is provided.

2. Analytical Model

The network diagram illustrated in Fig.1 is chosen from the entire spectral composition, one spectrum band is preferred and is shown. The base station grants access to the channels and whose task is to provide a good QoS for the PUs and then cater to the needs of the SUs with the help of a coordinator (or a relay station). When a secondary user requests access to a channel, the SU relay station senses the environment and if any channel is idle, it gives SU the access by communicating with the base station [7]. When a relay station for the SUs senses presence of an active PU then it performs spectrum handoff for the SUs and dynamically allocates some other channel to it. The secondary transmission range is shown in the form of a dotted ellipse because it is expected that the system shall be in a position to perform a power adaptation in case the SU becomes mobile.

Let us discuss about several issues with which the proposed algorithm has been developed. Consider when a Secondary user's (SU) receiver drifts away from the SU transmitter as shown in Fig.2, the relative distance between the Transmitter-Receiver pair changes diving room for sacrificing the quality of communication. Another possibility is that the SU receiver exits the transmission range. This in turn may lead to a communication drop.

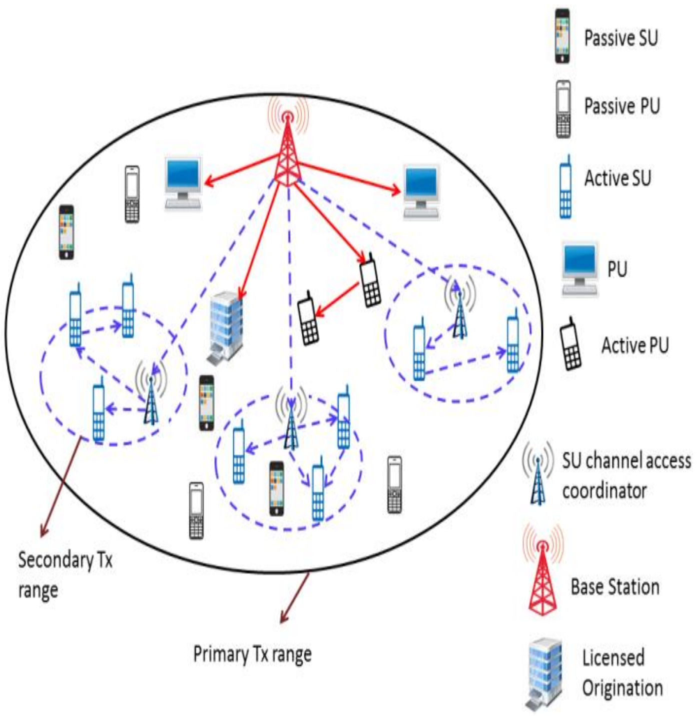

Figure 1: Network Diagram

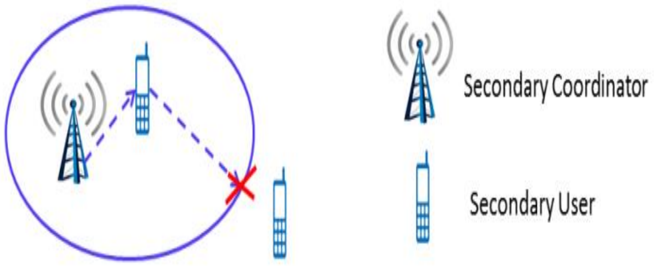

Figure 2: Mobile SU Receiver

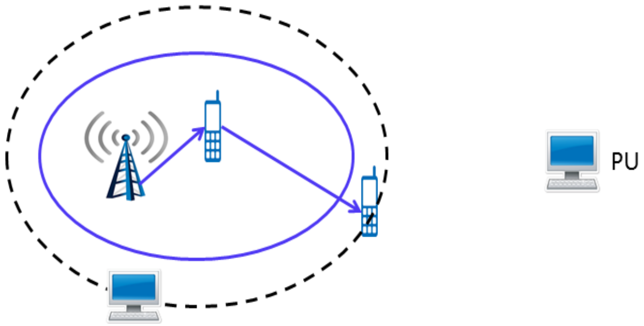

Figure 3: Presence of Active PU's

It implies that to maintain satisfactory quality levels of communication between SUs, it is so important to equip them with power adaptation technique. Power needs are to be adapted with the help of mobility information available about the SUs. However, in case the primary users (PUs) are in the additional transmission range, interference [4] by the SU transmission is a possibility, as shown in Fig.3.

If the PU is active, then the SUs are expected to perform spectrum handoff and do a dynamic search to arrive at another available channel to carry on their communications. Meanwhile, during the power

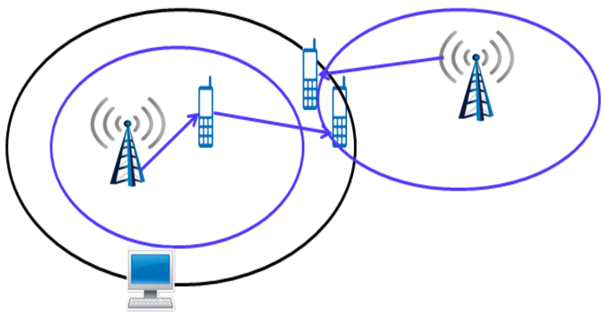

Figure 4: Adjacent Channel Interference

adaptation process, if the transmission power becomes too large,then it may causeundueinterferenceto the adjacent channel users as shown in Fig.4. This implies that whenever the transmission scope of a SU who uses a channel gets increased beyond the tolerance limits of the users at nearby frequencychannels, then it may lead to disruptions in communication [8]. In such a case power equalization can come to rescue to prevent undesirable interference. The other way is that when power equalization is impossible, it signals for a spectrum handoff for the SU that poked the disturbance.

Since spectrum handoff terminates the on-going SU communications, this degrades the SU performance. And also when the transmission power becomes too high through power adaptation technique, it leads to a reduction in communication quality for other users. An optimal strategy has been designed that jointly performs power adaptation- equalization and spectrum handoff to keep up a balance and proper execution in the framework.

Power Adaptation Scheme

The working model of the proposed power adaptation scheme is illustrated in fig.5. The aim is to sustain a better communication to the mobile secondary users. The combined SU transmitter and the relay station are depicted in fig 5. Obviously the transmission range depends on how far is the position of a SU receiver from that of the tower.

The figure shows that the initial distance between the relay station and the SU receiver is 'r'. Next it is assumed that the SU receiver starts moving away at a constant velocity 'v_s', either from the relay station or from the SU transmitter in a direction as shown in the fig 5. The subsequent positions of the SU receiver are also shown. The bold ellipse represents the initial transmission range and the concentric dotted ellipses are the successive transmission ranges, after power adaptations are performed. The magnitude of the velocity of the SU receiver is also known to the relay station. The SUreceiver moves in a direction subtending an angle'φ' with the respect to the line drawn from the centre of the ellipse.

In this scheme the equation is derived for the increase of SUs transmission power by utilising the two-ray ground reflection model, which yields the received power as follows:

$$P_r = \frac{P_{st} G_{st} G_{sr} h_{st}^2 h_{sr}^2}{r^l} \qquad (1)$$

where $'P_{st}'$ is the power of transmission; $'G_{st}'$ and $'G_{sr}'$ are the gains of the transmitter and receiver antennas of the secondary user; h_{st} and h_{sr} are the antenna heights of the SU transmitter and receiver individually; "r" is the distance of separation between the transmitter and the receiver; and "l" is the path loss factor (it is the reduction in the power density of the signal as it engenders through the environment; free space losses, absorption losses, diffraction, multipath, obstructing terrain and buildings are the major causes). Two-ray ground reflection model considers both direct path and ground reflection path between the SU transmitter and SU receiver. And the model gives more accurate prediction for longer distance. Upon choosing this model, (1) gives a faster decrease in power with an increase in distance.

$$P_{st} = \frac{r^l P_r}{G_{st} G_{sr} h_{st}^2 h_{sr}^2} \quad (2)$$

So as to maintain continuous communication for SU, the process of power adaptation for SU transmission take time. Hence, the performance analysis has to be done periodically.

Considering, the magnitude of the velocity of the SU receiver as ‘v_s’ (constant), so after a lapse of δ_{st} seconds the distance that it would have traversed will be ‘$v_s \delta_{st}$’ unit lengths. The effective component of this distance along the centre is given by ‘$v_s \delta_{st} cos\varphi$’. After ‘$m$’ power adaptations, the distance that the SU receiver would have travelled will be‘$m v_s \delta_{st} cos\varphi$’’.

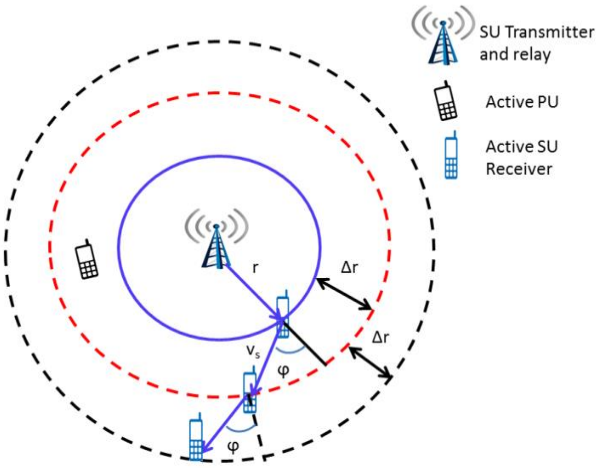

Figure 5: Power Adaptation Model

$$P_{st}(m) = \frac{(r + m v_s \delta_{st} cos\ \varphi)^l P_r}{G_{st} G_{sr} h_{st}^2 h_{sr}^2} \quad (3)$$

After $(m+1)$ adaptations, the transmission power becomes:-

$$P_{st}(m+1) = \frac{[r + (m+1) v_s \delta_{st} cos\ \varphi]^l P_r}{G_{st} G_{sr} h_{st}^2 h_{sr}^2} \quad (4)$$

The difference between two consecutive sequences of power adaptation, P'_{st} is given by:

$$P'_{st} = P_{st}(m+1) - P_{st}(m) \quad (5)$$

Therefore, due to the power adaptations, the transmission range of the SUs increases. This however can cause interference to the authorized users present in the additional transmission region. Hence, now the consideration is to look at the probability whether the PU will be active or inactive.

Probability of Finding an Active Primary User

In Fig.5 $'r'$ denotes the initial distance between the relay station and the secondary user receiver which can lie between the range $(0, a)$; where $'a'$ and $'b'$ are the semi-major axis and the semi-minor axis of the ellipse. Now, since we have assumed that the power is being adapted at equal intervals of 'δ_{st}' and that the secondary user receiver moves with a constant velocity 'v_s', the change in the transmission area will also be uniform. So the increment in the major axis and minor axis is considered to be the same i.e., 'Δr'. 'Δr'which is equal to '$v_s \delta_{st} cos\varphi$'. Therefore, the length of the major axis and minor axis after the first power adaptation will be '$(2a + \Delta r)$' and '$(2b + \Delta r)$' respectively.

The original transmission area $A_0$is equal to 'πab'. The transmission area after the first power adaptation will be

$$(A_0 + \Delta) = \pi \left((a + \Delta r)\right)\left((b + \Delta r)\right) \qquad (6)$$

Thus the area of the additional transmission rangeA_D is given by :

$$A_D = A_0(m+1) - A_0(m) \qquad (7)$$

$$A_D = \pi v_s \cos\varphi[(m+1)\{a + b + (m+1)v_s \delta_{st} \cos\varphi\} - m\{a + b + (m)v_s \delta_{st} \cos\varphi\}] \qquad (8)$$

Also the total network area is $A_L = LB^2$ ('L' is the side length and 'B' is the side breadth). We consider that PUs are uniformly circulated inside the system region, (refer Fig.1); so the probability that 'p' PUs are present within A_D is:-

$$P(p) = {}^K C_p \left(\frac{A_D}{A_L}\right)^p \left(\frac{A_L - A_D}{A_L}\right)^{K-p} \qquad (9)$$

where'K' is the total no. of primary users in the network. Furthermore, we characterize the likelihood that a PU is alert 'ρ' as:

$$\rho = \frac{E[active]}{E[active] + E[passive]} \qquad (10)$$

Now, given that 'p' primary users are present in the additional transmission zone, the probability that out these 'p' users 'g' of them are active is given as

$$P(g/p) = c_g^p (\rho)^g (1-\rho)^{p-g} \qquad (11)$$

Assuming the total number of channels to be 'N'. Then the probability of choosing channel 1 will be

$$P = 1/N \qquad (12)$$

Given that there are 'g' awake primary users in the additional transmission zone, the probability of 'h' primary users out of 'g' actively using channel 1 is given as:-

$$\mathrm{P(h/g) = C_h^g (P)^h (1-P)^{g-h}} \qquad (13)$$

Combining Eq. (9), (11) and (13) to obtain the probability of finding a PU in the additional transmission zone that may require the access on the channel which the secondary users is currently using for its transmission needs is given as

$$P = \sum_{p=1}^{K} P(p) \sum_{g=1}^{p} P(g/p) \sum_{h=1}^{g} P(h/g) \qquad (14)$$

Circumstances for Spectrum Handoff

In order to avoid collisions among the licensed and unlicensed users, spectrum handoff is to be performed. The following explanations enlight better clarification. Fig. 6 illustrates the ongoing unlicensed user transmission process. Here the unlicensed user utilises channel 1. It was found that at the time 't_0' the authorized client moves in for utilizing the same channel as that of the unlicensed client. In such a case the unlicensed user shall forego its transmission process.

There are two options where the unlicensed user can resume transmission. The first one is to wait till the licensed user complete transmission and then recommence or else the other choice is to perform a spectrum handoff and go to another channel. Since the former generally causes a long delay, in this ventured scheme the second method is chosen.

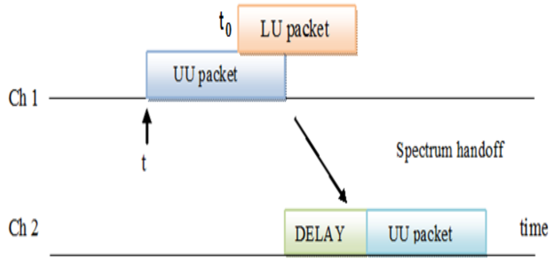

Figure 6: Condition When the Licensed User Wants to Access the Channel

In order to develop an analytical model for calculation of throughput of the unlicensed user the following steps are done. First, make use of the queuing theory that helps to formulate conditions in which the throughput is to be calculated. According to the Queuing theory, If the service rate is greater than the arrival rate the queue will tend to stabilize, but if the service rate is lesser than the arrival rate the queue will increase in length without limit and hence a remedy would be required. The remedy that is required in the scenario presented in the above statement is for spectrum handoff. To calculate the throughput, it is assumed that the SU packets arrive as an exponentially distributed random variable X with density function. The reciprocal of this expected value is referred as the arrival rate. So, the standard arrival rate of SUs is λ_{sa} packets/ Sec. The service time is defined as the time that SU uses the channel. Let it be denoted as X_{ss}. From the above mentioned statements about the queuing theory, two cases can be developed and they are as follows:-

- When the service rate is greater than arrival rate i.e., $1/X_{ss} > \lambda_{sa}$, which means that the unlicensed user traffic is unsaturated.

- When the service rate is lesser than arrival rate i.e., $1/X_{ss} < \lambda_{sa}$, which means that the unlicensed user traffic is saturated.

Now the following assumptions are made: let the throughput of the SUs during spectrum handoff be T_{S2}. In addition the throughput of the SUs without the requirement to change the channel be i.e., without spectrum handoffs be T_{S1}. And when there is a collision without a spectrum handoffs, then let the throughput in such a case be T_{S3}.

Case 1 : Unsaturated Case

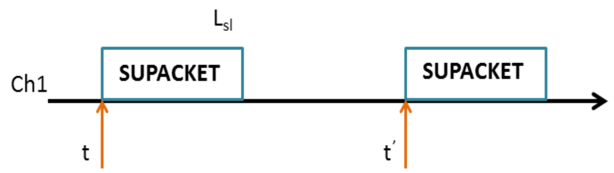

Figure 7: No Collision and No Spectrum Handoff

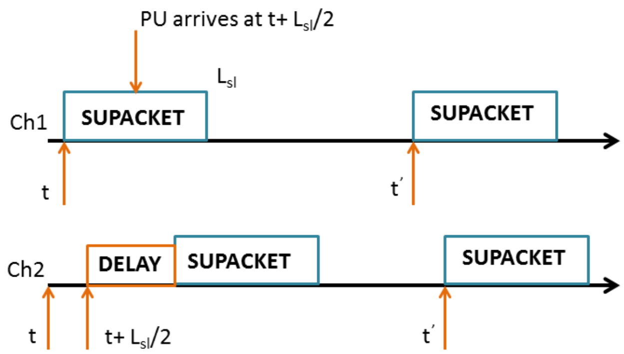

Figure 8: Spectrum Handoff Case

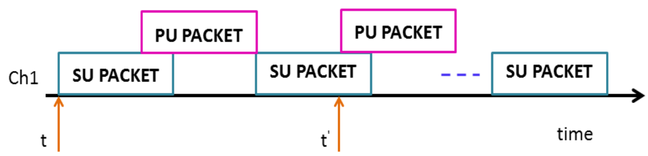

Figure 9: Saturated Case

As shown in the Fig.7, i.e., the case without any spectrum handoff, the throughput T_{S1} will be equal to the arrival rate, because it is at this rate that the unlicensed user is transmitting data without any spectrum handoff.

$$T_{S1} = \lambda_{sa}\, packets/s \qquad (15)$$

However, in case of a spectrum handoff, Fig. 8 the unlicensed user might have to experience a delay while the network is in the process of dynamically allocating the user an available channel. So T_{S2} becomes;

$$T_{S2} = \frac{\lambda_{sa}}{delay + X_{ss}} \tag{16}$$

Case 2 : Saturated Case

Now consider the second case which is to calculate the SU throughput. Here, the waiting time is the time SU packets have to wait in the queue, before they start to get transmitted.

$$T_{S1} = \frac{\lambda_{sa}}{X_{ss} + waiting\ time} \tag{17}$$

And the throughput T_{S2} will be

$$T_{S2} = \frac{\lambda_{sa}}{L_{sl} + delay + \frac{L_{sl}}{2}} \tag{18}$$

where, L_{sl} is the average packet length of SU (time slots : s).

Case 3 : Collision Case

Next calculation is the throughput of the SUs when there is a collision. The SUs in such a case shall abort the on-going transmission process. So the throughput T_{S3} becomes:-

$$T_{S3} = \frac{\lambda_{sa}}{L_{sl} + C \times L_{pl} + C \times \frac{L_{sl}}{2}} \tag{19}$$

whereL_{pl} is the average packet length of licensed users and C gives the number of collisions.

Test Hypothesis

The ‘detection probability’ can be termed as a metric that is used for doing the ‘correct detection’ by CRN related to the absence of primary users on a particular channel. The 'miss-detection' likelihood is likewise a metric for CR that implies the inability to distinguish the nearness of an essential client who needs the access to the channel. Similarly, in this case, there are two situations with different likelihoods in the whole sample space. The system shall take a decision amongst these two, repeatedly or iteratively to maintain efficiency of the network. Sensing can be seen as a binary hypothesis testing problem(twofold speculation testing issue) with hypotheses H_0 and H_1. Now a Hypothesis test problem is formed since a correct decision is to be arrived between two events. Based on the analysis done in the sections (2.1, 2.2 and 2.3), a condition is achieved to decide whether the unlicensed users should perform spectrum handoff during power adaptation or not [15].

Let $'H_1'$ stands for the secondary users, who must perform spectrum handoff and; $'H_0'$ means secondary users who are not performing spectrum handoff. Thus the test hypothesis can be developed as:

$$T_{S2} \gtrless_{H_0}^{H_1} T_{S3} \times P_r + T_{S1}(1 - P_r) \tag{20}$$

If the term on the left hand side is large; then the system decides in favour of spectrum handoff, else it decides not to undergo spectrum handoff. The threshold value η is formulated to be $(H_1)/(H_0)$.

Power Equalization Scheme

Water-filling algorithm is a common name that is given to the power equalization schemes for the channels in communication systems design [14]. Water filling is utilized to tackle the issue of power allocation which can be expressed as follows: Suppose there are 'm' independent sub-channels with a noise power of N_i, where $i = 1,2,3 \dots .m$. The transmitted signal power is given by 'S'. Water filling algorithm is used when it is wanted to distribute this signal power among the 'm' sub-channels, such that maximal total capacity is possible.

The Shannon capacity theorem gives,

$$C = B \log_2(1 + S/N) \quad (21)$$

where C is the channel limit, B is the data transfer capacity (bandwidth) and 'S' is the signal power and 'N' is the noise power. In orthogonal frequency division multiplexing (OFDM) cognitive radio networks the power allocation schemes are very convenient and flexible too [9-10]. However, it is quite challenging to allocate the power to individual sub-channels. The conventional water filling algorithm [14] cannot be directly used for Cognitive radio systems since considering increased 'power constraints' and 'additional interference constraints' are there. So in this paper, it is pioneered to implement the iterative water filling algorithm, but with a smaller complex method with 'power increment' or 'power decrement' process. This has been done because the complexity of the computational process is tedious rather unwieldy for an iterative water filling algorithm.

Fig. 10 shows the working diagram of this scheme. Here the emphasis is that the secondary user can have different detection and interference regions. The Secondary user transmitter (or relay station) is situated at the centre of the diagram and 'd_0' is the distance from the SU transmitter upto the boundary of the detection region (this is the zone the signal transmitted by SU transmitter can reach SU receiver). 'd_i'is the distance from the centre to the interference region boundary. In such a case the optional client transmitter will most likely have the inability to distinguish the nearness of the primary user 2 due to a huge separation between them (d''). The primary user 2 has an elliptical protection region whose distance from the centre to its boundary is given as $d'[range : (0, a); a : semi - major\ axis]$

in such a situation the secondary user's power can never exceed a stated threshold. The primary users too shall abide by the power constraints and control their transmission powers. Hence the task for the secondary users is to secure primary users in the same region. Nonetheless, if the essential client collector lies outside the obstruction zone, then the optional client will not cause any harmful interference, even if the stated threshold value exceeds.

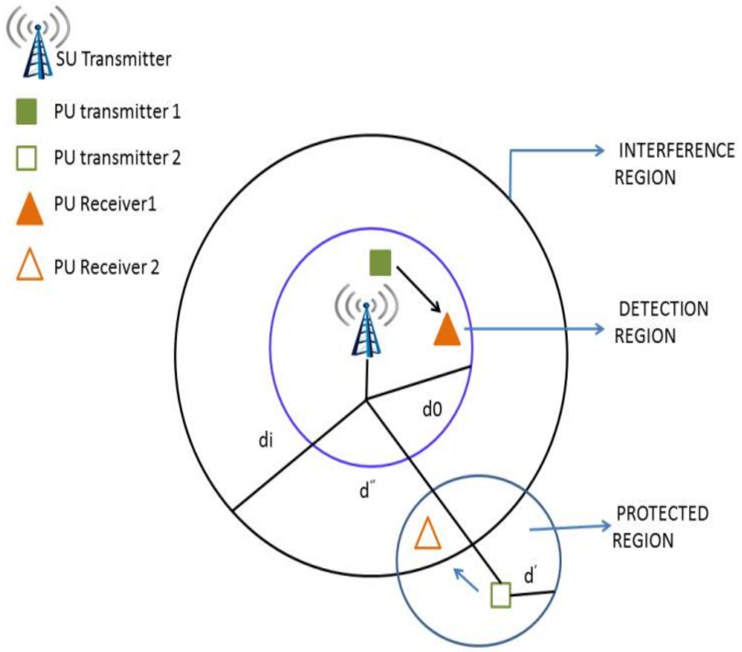

Figure 10: Power Equalization Model

In this model each sub-channel is allocated to a particular primary user. Let there be 'K' sub-channels corresponding to 'K' primary users. Let each sub-channel contain $L_i(i = 1,2,3 \ldots\ldots K)$ no. of different sub-carriers with different channel gains. So the total number of sub-carriers are given by

$$Q = \sum_{i=1}^{K} L_i \; (22)$$

In opportunistic spectrum access cognitive radio system [13], as discussed before the secondary user cannot use the channel if the primary user wants access it. Meanwhile, when the primary users are not detected, there is a need for the secondary users to keep the transmission power under a particular threshold. This condition can be written as:

$$P_i \leq G_i \qquad (23)$$

Where $G_i$is given as

$$\begin{cases} 0; when\ the\ i^{th}\ \ primary\ u \\ \quad user\ is\ detected \\ \eta\left[d_i{}'' - (d')^i\right]^{\alpha};\ when\ the\ i^{th} \\ primary\ user\ is\ not\ detected \end{cases} \quad (24)$$

$P_i$is the power allotted to the unlicensed users in the sub-channel 'i' and 'η' represents a specific threshold. For simplifying computation, the threshold value for all sub-channels is considered to be the same. $G_i$is the interference constraint for sub-channel 'i' (the transmission power shall not cross the stated value as it can potentially interfere with the hidden primary users, i.e., the users are out of detection zone but inside the interference region). $di''$is the separation between the secondary user and primary user transmitters. And $(d')^i$ denotes the protection region of the sub-channel 'i'. 'α'here represents the path attenuation factor. In 'K' sub-channels, the 'interference constraints' depend on various essential clients. So currently 'K' diverse interference constrictions are considered. The issue of power distribution is planned as:

$$P^* = arg\,max \sum_{j=1}^{Q} log_2(1 + P_j H_j)\frac{B}{N} \qquad (25)$$

such that $P_j > 0$ and where P_j is the allocated power of each subcarrier; B is the data transmission (bandwidth) of the channel and H_j is the channel to noise ratio (CNR) i.e., the noise power for subcarrier j. 'F_i'is the total power allocated to the sub-channel 'i'.

$$\sum_{J=1}^{Q} P_j \leq P_{tot} \qquad (26)$$

$$\sum\nolimits_{j \in Jj} P_j = F_i \leq G_i \qquad (27)$$

The above two equations add interference constriction to every sub-channel. Here the power distribution is liable to two kinds of constraints, one is total power constraints and the other is individual sub-channels' power constraints. So a 'dual layer power allocation constraint' is there. Two sets of sub-channels A and B are considered. Initially the set A consists of all the sub-channels and the set B is a null set.

So after the first run through the water filling calculation is played out, the sub-channels with $F_i > G_i$ will be progressed from set A to set B. And this extra amount of power is re-distributed to the sub-channels satisfying the condition $F_i < G_i$. This process is known as water re-filling process as the power is re-flowing from the set B's sub-channels to set A's. This is the reason why the common water level will eventually increase and more sub-channels will be placed in set B.

Some of the water in the set B's sub-channels will be pressed to set A's sub-channels. When this flowing and re-filling process is stopped, the steady state will be reached. By utilizing this calculation one can get the ideal power distribution for the sub-channels.

This plan is practically equivalent to the uneven barometric pressure model. In this model the pressure on the distinctive water levels is more prominent than the pressure on the shared view level. Because of the way that there are diverse pressures on the sub-channels, the water will not spill out of one channel to another regardless of the fact that the levels are different. So the uneven but steady state will still achieve the maximum capacity.
The steps involved in the water-fill algorithm are briefly explained in Table 1:

Table 1: Water-Filling Algorithm

Initialization		
Step 1	:	$A = \{ i = 1,2,3 \ldots\ldots K\}, B = \varphi$ and $P = P_{tot}$ Run the traditional water-filling process for set A with P and find the water level 'y'
Step 2	:	the sub-channels are moved to set B if $F_i > G_i$and then update the set A.
Step 3	:	Execute power decrement on set B and power increment on set A with $\Delta = F_i - G_i$. Now update the common water level 'y' and 'F_i'
Step 4	:	if$F_i > G_i$then goto step 2.

3. Performance Evaluation

In this area, we assess the execution of the proposed collaborative scheme of power adaptation-equalization and spectrum handoff using the MATLAB simulation tool.

Simulation Parameters

The parameters utilized as a part of our plan are examined in this area. It is assumed that the power required by the Secondary users to maintain their transmissions should be at least 1W.

The initial distance between the secondary user pair of transmitter and receiver is considered to be 5 m. The simulation area, i.e., the total area is assumed to have a side length of 500 m, making the total area to be 0.25 km2.

Also a time-slotted system is adopted for this paper. The Table 2 enlists the parameters with their values listed.

Table 2: Simulation Parameters

Parameters	Values
Number of Secondary users	2
Number of Primary users (K)	25
Number of channels (N)	15
Number of sub-carriers	32
The side length of the total area	500 (unit lengths)
The initial distance (r)	5 (unit lengths)
The power adaptation interval time (δ_{st})	0.1 second
The probability of having an active PU	0.85
The time slot (β)	0.002 (second)
The total simulation time (t)	1(time units)
The average speed of SU (v_s)	10m/s
Mean length of time slot (L_{sl})	50

For the mobile characteristics of the secondary user receiver it is assumed that the speed at which it moves is constant and that the angle 'φ' is 300. The length of the packets despatched by the optional client transmitter is conceived to be an exponentially distributed function whose mean length L_{sl} is stated in the Table 2. The packs sent are distributed in a poisson stream design with normal the arrival rates of 2, 5, 10, 15 and 20 packets/s.

Simulation Results

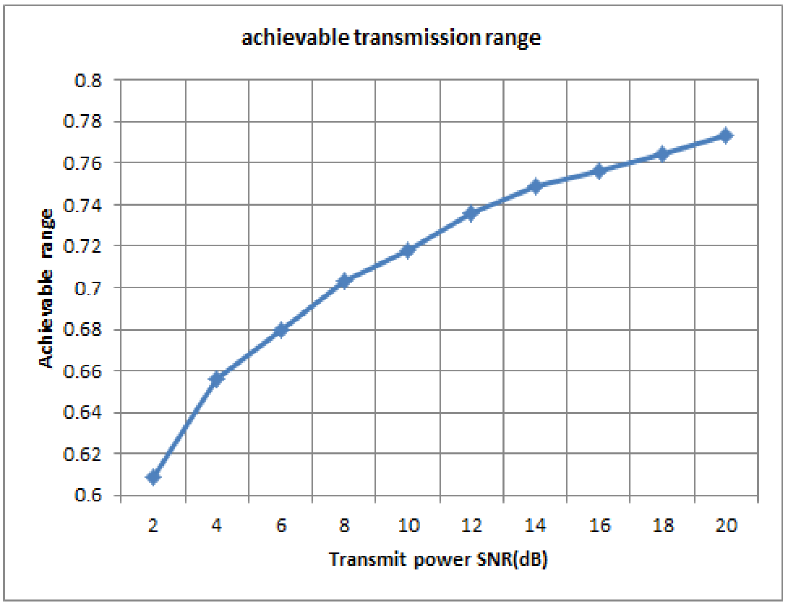

Figure 11: Increase in Tx Range with Power

In the Fig. 11 one can observe that when the SU Rx moves away from the Tx, the system senses it and increases the transmission power to provide for an increased coverage.

This power adaptation process is evident from the graph.When the threshold value is greater than the optimum value, the system decides to initiate the spectrum handoff process which reduces the throughput of the SUs due to the delay involved in such a process. This can be observed from Fig.12.

Comparison of throughput is made with respect to arrival rate for various velocity values; it has being observed that for a particular arrival rate, the throughput decreases with velocity.

If the SU starts to move with very high speed then fast power adaptations may lead to a decrease in the throughput. Else if the speed is moderate, the throughput remains high as illustrated by the Fig. 13. Approximately there is about 7-8% of improvement in throughput is achieved under spectrum handoff.

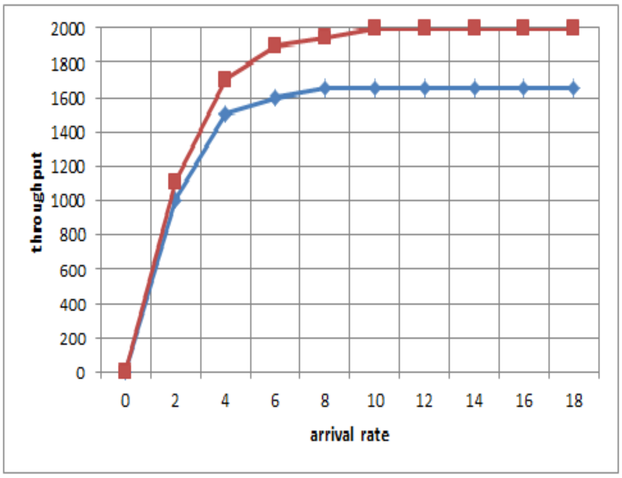

Figure 12: Throughput Under Different Thresholds

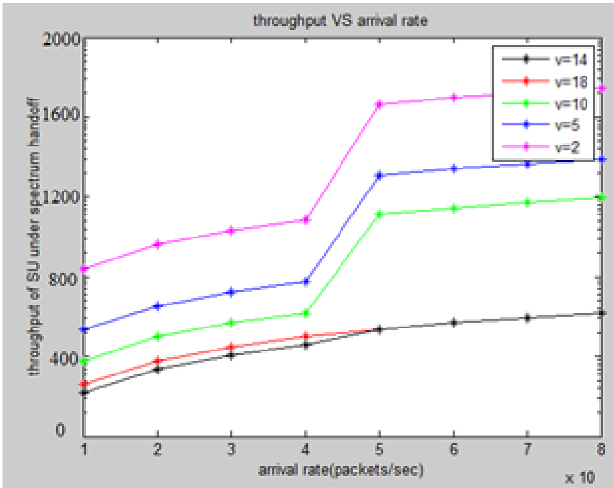

Figure 13: Throughput Vsarrival Rate

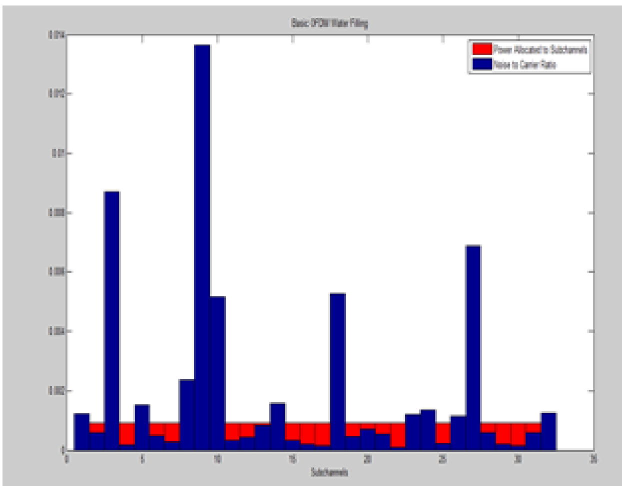

Figure 14: Power Equalization Process

If the adjacent channel's noise to power ratio turns out to be too high, then the SUs are required to undergo spectrum handoff. The system will then dynamically allocate the channels that have minimal noise power as shown in the Fig. 14.

4. Conclusion

This paper puts forth a collaborative power adaptation-equalization and spectrum handoff scheme for a mobile cognitive radio network. The scheme yields power adaptation in circumstances where the secondary user happens to be a mobile one. As explained above this is vital to sustain a good quality of communication among the SUs. Next the spectrum handoff scheme's objective is twofold, one is to provide primary users the accessibility to channel whenever a request turn up, that too with a minimal delay. The second is to alleviate the harmful interference posed to the proximate users due to a rise in transmission power. In addition, the power equalization scheme is poised to bring down the power levels to permissible limits or signals for a spectrum handoff. Simulation results validate that the throughput of the SUs can be effectively bettered by adopting the laid out algorithm offered in the early sections of this work.

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