Efficient Spectrum Handoff Strategies in Cognitive Radio Networks

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Abstract— In Cognitive Radio (CR) systems, the spectrum handoff which is affecting to the performance of system by main factors such as: link maintenance probability, the number of spectrum handoff, switching delay. Spectrum handoff may be happen more than once for a wide range of the spectrum available in CR. This switching change the characteristics of propagation transmission loss which is affects the overall system performance. Thus, in this paper, the path loss and coverage area are essential factors studied to enhance the system performance and make it more immune to propagation losses. In this article, we aim to overcome these issues by proposing a systematic selection method to select and assign new appropriate frequency channels efficiently to achieve a better transmission performance. Additionally, the adaptation power technique is applied in order to control base station transmitted power and estimate the appropriate coverage area to reduce and avoid interference an+d also to conserve power dissipation in the system.The combining of these approaches, selection method and power adaptation, is found to be helpful to achieve an efficient spectrum utilization, reduce power consumption, maintain the connectivity link, decrease the number of spectrum handoffs from failure which are very important to improve overall system performance. The simulation results show a comparison of the proposed strategy with other techniques by increasing the wide of frequency switching up to 64% and also studies the effect of the adaptation technique on the system performance.

Index Terms—Cognitive Radio, Spectrum Handoff, Power Adaptation.

I INTRODUCTION

Cognitive Radio (CR) technology is considered a solution for the efficient usage of RF spectrum. The CR can communicate on the channel selected only as long as it is available, it will need to vacate the channel when the owner of the channel which is the licensed user arrives back on the channel. This is the spectrum mobility. The CR device is a secondary user (SU) that operates in the band licensed to the primary user (PU). Here the SU in CR has to make sure that it avoids any harmful interference with the licensed channels at all costs. The SU will make evacuate the channel upon the arrival of PU. After vacating the channel, the SU will need to resume its transmission to complete it. In order to do that, the SU needs to suspend its transmission temporarily and handoff to another vacant channel; this kind of handoff is termed as spectrum handoff. Handoff here means switching to another channel to resume transmission [1]. Spectrum handoff is a very challenging issue in CR networks because it plays a key role in deciding the next target channel, i.e., the channel on which the SU will resume its transmission after vacating its current operating channel for the PU. The activity of PUs is arrivals randomly; it makes it very difficult and urgent to accomplish a seamless transition which is fast and smooth with minimum performance degradation during the spectrum handoff process. Performance degradation issue is basically associated with the amount of delay caused during the spectrum handoff process. The more delay caused and compromised will be needed on the performance of transmission. Spectrum handoff delay depends on the handoff scheme used in spectrum handoff process. The performance requirements for CR system are: reliable spectrum hole and PU detection, accurate link estimation between users, fast and accurate frequency control and power control method that assures reliable communication between CR terminals and non-interference to PUs. In a CR, adaptations to the physical layer will ensure a communication channel with certain guarantees for bandwidth use and data throughput. To know the performance of our whole system as well as the performance of parts of it we need to decrease number of handoff as important impact factor performance of systems.

The major purposes of spectrum handoff for CR system are to reduce interference to PUs and to avoid service block and even connection loss for SUs. Thus, when PUs appear, SUs must vacate licensed bands and sense idle bands. If SUs cannot find an available band in a cell, their transmission may be interrupted. Otherwise spectrum handoff happens. Additionally, when PUs appear frequently, spectrum handoff may result in degraded system performance due to the excess of spectrum sensing and spectrum handoffs. For that reason, some researchers proposed algorithms to reduce the number of spectrum handoff and to increase the capacity of SUs while others focus on the channel switching algorithms and switching time delay. A novel spectrum handoff scheme is proposed considering a power control based spectrum handover scheme which intelligently adjusts the transmit power of the SU, greatly reduce the spectrum handover ratio and improve the effective data rate of the transmission efficiency by avoiding some of the handoffs [2]. The effect of the different path loss on the different frequencies used in the spectrum handoff and develop an algorithm that try to overcome the limitations of this effect [3]. The quality of service (QoS) can degrade significantly due to a change of frequency which reduced the outage probability. The spectrum access scheme of unlicensed channels as backup improves and characterizes the spectrum handoff performance: link maintenance probability, the number of spectrum handoff, and switching delay [4, 5]. The spectrum decision algorithm based on prediction is proposed to decrease spectrum handoff probability which can achieve fewer disruptions to primary transmissions by letting SUs proactively predict the future spectrum availability and perform spectrum handoffs before a PU occupies the current spectrum[6,7]. Wang et al. in [8] and Zhang et al. in [9] use queuing network model to discuss the effect of proactive sensing and reactive sensing on spectrum handoff to characterize the spectrum usage behaviors between primary and secondary users in CR networks dependent of sensing time. Voluntary spectrum handoff is used to reduce temporary communication disruption time. The proposed approach is based on a fixed sensing window, a variable history window and the reduced forced spectrum handoffs. Using this approach, SUs can have longer undisrupted connection [10]. In this proposed strategy, we present the systematic frequency selection scheme joint with adaptation power of transmitter base station to optimal usage of spectrum resource. Also, improvement the overall performance CR system, reducing spectrum handoff from failure and decreasing the interference and power dissipated will be presented.

II SYSTEM MODEL:

This section presents the CR system model. So, instead of a large multi-hop mesh network. It is reasonable to simplify situation to a single-hop wireless network and concentrate mainly to the CR concept.

In the CR system model the PUs do not need to know anything about CR devices, and there is no need to modify existing systems, which is thought to be a basic prerequisite to a CR system. It is important that the licensed PUs can still operate in the conventional way even in the presence of the CR system.

2.1 System Model Description

In this work, the general CR system model for our studies is presented in Figure 2.1. The cognitive radio system model includes PUs and SUs and it coexists with a CR each to other. Assuming the primary links is operating in any channel in the primary coverage area. Then the SUs are allowed to use the channels other than channel occupied inside the coverage of the primary transmitter base station. In the figure 2.1, the dimensions are illustrated only for the systems, the numbers and locations of the users.

At the beginning of network operation, the locations of PUs and SUs are chosen randomly in the network area using uniform distribution and it is a possible for SU to detect the presence of PU.

There are number of methods to achieve and detect the unoccupied channel (spectrum hole) such as sensing process using the SUs or / and geo-location database which updated from national body regulators since a SU would only need to report its location to the database and in return receive information regarding the spectrum availability and associated constraints.

When the current spectrum hole conditions become worse, or the PU appears and reclaims his assigned channel, SUs need to stop transmitting data and find other available channels to resume their transmission.

Since the transmissions of SUs are suspended during a spectrum handoff, they will experience longer packet delay. Therefore, a good spectrum handoff mechanism should provide with secondary users with smooth frequency shift with the least latency. When SUs need to switch to another frequency, they can immediately pick one channel from the reserved bands. Whenever a handoff becomes a must, SUs can switch their frequency to one of the candidate channels depending on their locations.

Proactive decision spectrum handoff is adopted in this work, so it is considered based on the moment when SUs carry out spectrum handoffs and it makes the target channels for spectrum handoff ready before data transmission according to the long-term observation outcomes. The proactive decision spectrum handoff may be capable to reduce handoff delay because the time consuming wideband sensing is not required.

Furthermore, it is easier to let both transmitter and receiver have an assent on their target channel for the proactive decision spectrum handoff than for the reactive decision spectrum sensing. Nevertheless, when the spectrum handoff process is initiated, the proactive decision spectrum handoff needs to account the issue of pre-selected target channel may no longer be available.

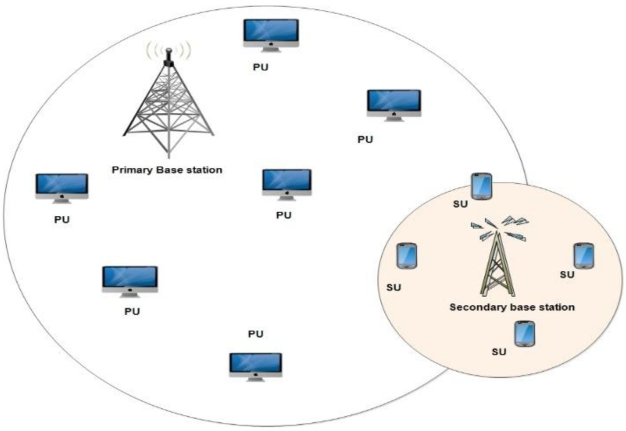


Figure 2.1: The Coexistence system model of PU and SU.

The tasks of the CR base station include spectrum sensing at the receiver for identification of spectrum holes, transmission of the sensing information to the transmitter side of the link via the feedback link. Also the base station control channel, and frequency and power control at the transmitter via the feedback information from receiver and control information from the base station [7].

The role of CR base station differs from conventional access point because it has now cognitive capability and the communication between SUs is peer-to-peer (P2P) type communication. The locally sensed spectrum information of SUs will be sent to a common control channel, combined in the secondary base station, and then broadcasted to the CR users in the network [11].

2.2 Frequency Changing and Path Loss

CR system has emerged as a new solution to the increasing demand of wireless communications and improved the spectrum utilization, so that the available list of frequency channel is extended which is obtained from the sensing operation. In this wide spectrum frequency (pool), the frequency is changed from a higher to lower or from lower to the higher one as shown in figure 2.2.

The cell coverage (dashed cell is new state) will be reduced or expanded because of the larger path loss or smaller, since the frequency is significant factor to impact the path loss. The changing of frequency (spectrum handoff) considered as a significantly affect QoS of secondary users due to signaling overhead and different path loss [3].

Figure 2.2: Cell Coverage due to changing frequency (spectrum handoff).

Generally, a high frequency band has large path loss, and a low frequency band has relatively small path loss. Thus, the propagation characteristic according to the operating frequency should be significantly considered in CR systems. On the other hand, it has not been significantly considered in conventional communication systems; because the switching of channel frequency is transit to the same assign band, not widely band.

Clearly, it matters in CR system with the wide range of frequency band. There are several of path loss models, for examples, Okumura, Hata, Cost-231, Walfish, simplified free space and using based to environment area which may be urban, suburban, or rural. Suppose, we used as example, Okumura-Hata path loss model in urban areas, which is a one of the most popular models, shows the effect of center frequency on the amount of path loss as follows[38]:

$$L_{dB} = \alpha + \beta \log_{10} d - \gamma \quad 2.1$$

Where

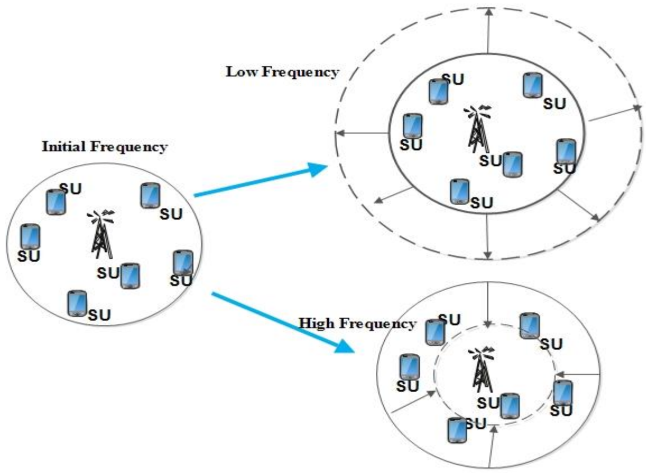
$$\alpha = 69.55 + 26.16 \log_{10} f_c - 13.82 \log_{10} h_b \quad 2.1a$$

$$\beta = 44.9 - 6.55 \log_{10} h_b \quad 2.1b$$

$$\gamma = 3.2(\log_{10}(11.7554 h_r))^2 - 4.97 \quad 2.1c$$

Above equation shows the path loss is very dependent on many factors such as center frequency (f_c), distance (d), height of base station (h_b), and height of receiver station (h_r). Especially, α describes the effect of frequency on the amount of path loss.

The frequency operating and distance (coverage area) are very important propagation characteristics. Suppose the height of base station (h_b) equal 10 meter and height of receiver station (h_r) equal 3 meter to calculate the effect both frequency and distance on the path loss.



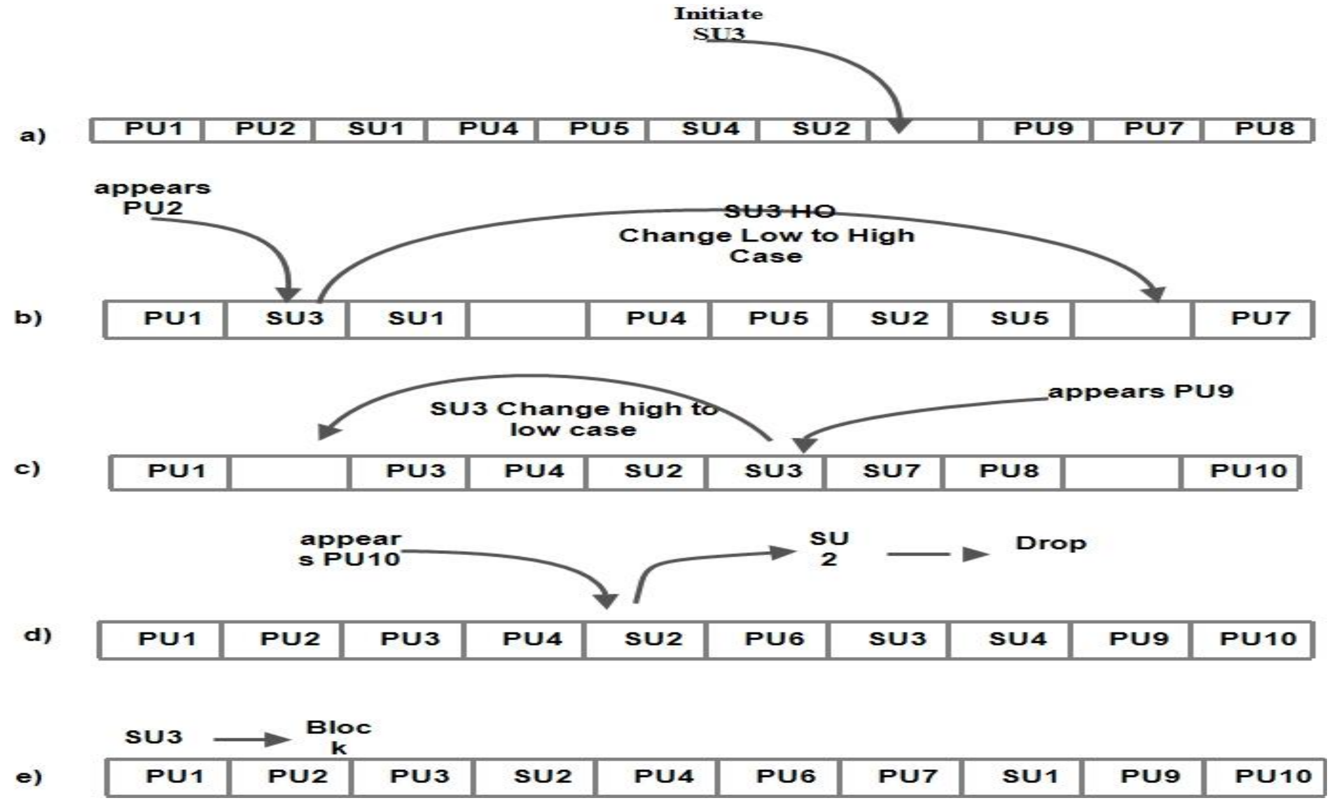


Figure 3.1: Spectrum Band (pool) random Selection (classic) a) Initial state select; b) Low to High HO; c) High to Low HO; d) Drop HO; e) Block HO.

First, for a given frequency the path loss increases with increased distance [3].

For example, put a frequency is a 450 MHz, the path loss increases from 151.86 dB at 10 kilometers to 178.67 dB at 50 kilometers. This difference of 26.8 dB can have a significant impact on the quality of the received signal in the system. Notice that for a factor of two increases in distance, the loss increases by 6 dB; again, this is characteristic of the path loss formula. It should also be noted at this point, there is a commonly used expression resulting from the path loss equation above that the free space path loss increases with the square of the distance between the two terminals.

The second important factor is that for a given distance the path loss increases with increased frequency. For example, put distance for 30 kilometers, the path loss increases from 156.5 dB at 100 MHz to 180.85 dB at 1700 MHz. Again, the 24.3 dB difference could have a potentially significant and detrimental impact on communications. Also, it should be noted that a factor of two increases in frequency will result in a 6 dB increase in the loss for the fixed distance. As another expression, path loss increases with the square of the increase in frequency.

2.3 Adaptation of Power Control in Secondary Base Station

In order to utilize the available spectrum more efficiently, a power control scheme is applied and incorporate into the proposed spectrum handoff selection scheme to reduce the number of spectrum handoffs and enhance the spectral efficiency.

In this work, by using the power control algorithm, CR station can determine not only primary channel's availability at its current location. Also it adjusts the power transmitter according to the check of the new frequency assign from handoff process is higher or lower to maintenance link. Moreover, it estimates a suitable coverage area to keep connection with the SUs; otherwise it switches to an idle frequency or the worst case the SUs blocking and out of service.

Frequency and power management is important and a suitable scheme to enhance the frequency bands and transmission power cost for the CR system. Thus, we have studied systematic channel selection and low complexity of power adaptation and incorporated to consume the power transmitter, reduce the number of spectrum handoff from failure and enhance the spectral efficiency.

III Spectrum Handoff Proposed Scheme

When the PU appears and asks for his assigned channel, SUs need to stop transmitting data and find other available channels to resume their transmission. This kind of handoff in CR networks is termed as spectrum handoff. Since the transmissions of SUs are suspended during a spectrum handoff; they will experience longer packet delay. Therefore, a good spectrum handoff mechanism should provide with secondary users with smooth frequency shift with the least latency.

When SUs need to switch to another frequency, they can immediately pick one channel from the reserved bands (pool). If PU is detected, then the SU vacate the channel as the PU has high priority and choose other from the pool randomly which may be higher or lower than the current state .The status of obtained new channel is either unoccupied, dropped or blocked as shown in the figure 3.1.

3.1 Systematic Selection with Power Adaptation

Using the estimation of the cell coverage as a basis in CR network , we propose a combined systematic selection channel frequency and power adaptation scheme that can reduce not only the total number of handoffs, but also reserve the power consummation and improve the overall performance of the system. The proposed algorithm spectrum handoff can be summarized into two stage scenario: the first stage is Channel frequency Selection, so it chooses between two paths which are systematic selection or random selection to pick the available new frequency due to spectrum handoff.

The second stage is power transmitter adaptation (power control), the decision of this stage is to apply the power adaptation or not and branching into four paths, each path produces the result based changing frequency and power adaptation. The results in the first stage may be changing from a low frequency to a high frequency (Low to High case), or spectrum handoff from a high frequency to a low frequency (High to Low case). In the Low to High case, coverage would be reduced, while in the High to Low case, it would be expanded. Therefore, it is more difficult to guarantee QoS in the Low to High case, because it is possible that cell outage will occur. In the Low to High case, we try to avoid cell outage by optimizing the power adaptation. Moreover, for the High to Low case, we propose another efficient scheme to reserve power transmitter overhead required that coverage area and avoiding interference with others networks.

In figure 3.2, the flowchart describes the algorithm in details, since we suppose any spectrum band service for primary system in real environment and if proposed another secondary system coexists in same area to exploit the spectrum band and efficiently improve the utilization of spectrum allocation scarcity. At detection of PU, the spectrum handoff decision needs to select any frequency to change it.

We can apply one of the two scenarios which systematic selection (proposed scheme) which is search from the beginning of the spectrum band (pool) to select the first unoccupied channel of the pool, while the other which is a randomly selection (classical scheme) is to obtain the new frequency randomly.

After selecting of the new frequency, the condition of power adaptation is applied. There are four paths which can be called power adaptation stage. So, the probability of new frequency selection may be low or high.

If it apply the adaptation power, then it calculate the power at new frequency and compared with maximum value of power system; if yes, estimate the coverage area at this frequency and adjust the power of transmitter base station; if no, put transmit power equal the maximum value power of the system and estimate the coverage area and force all SUs to execute the handoff.
At no apply the power adaptation; there are other two paths to comparing only with respect to changing new frequency to low or high. It estimate the coverage area according to new frequency selection and execute the handoff if any SUs out of cell.

3.2 Algorithm Procedures

From the previous, the algorithm can be executed in two stages. The first stage is channel frequency selection process, where consists of two approach, systematic selection (proposed) that is the proposed approach where the search selection channel begins from the first channel pool and moves to neighbor channel until the obtaining an available channel free to assign as channel handoff as shown in figure 3.3.The approach is random (classic) selection, presents in figure 3.1.

In the second stage, the algorithm consists of the need for the power adaptation or not to apply that on the result from selection scheme (may be high or low). With no power adaptation, the check is about new frequency selection only, since the coverage area is a reduced or expanded according to new frequency selection (spectrum handoff).

This approach do not put any solution or condition to overcome the majority of number a handoff generate from changing low to high and also, the interference creates from big cell coverage at switching from high to low. Thus, the adaptation power approach is considered to overcome the SUs of cell outage and eliminate the interference by optimizing the transmitted power of the cell coverage.

In power adaptation approach, the algorithm calculates the new transmitted power based on new frequency selection using the famous formula of power transmission which is the transmit power equal the receive power (power sensitivity) subtract path loss value. Then, estimate this value to coverage all SUs in the cell area (high to low case); otherwise use the maximum power of the system to estimate the cell coverage (low to high). From this approach, the reserved power is achieved and the number of handoff is decreased as shown in the simulation results in next section.

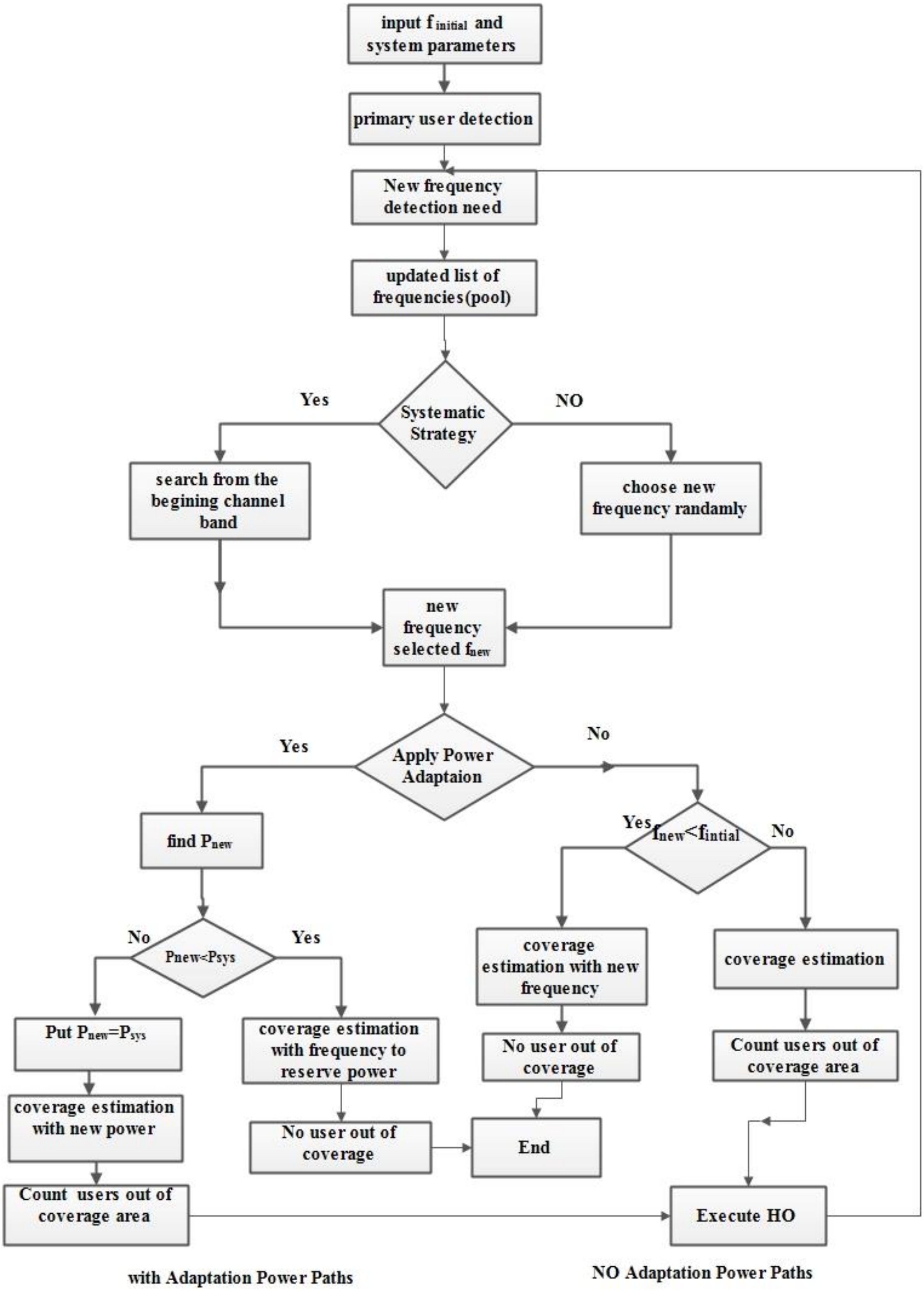


Figure 3.2 : Flowchart Algorithm Proposed Scheme.

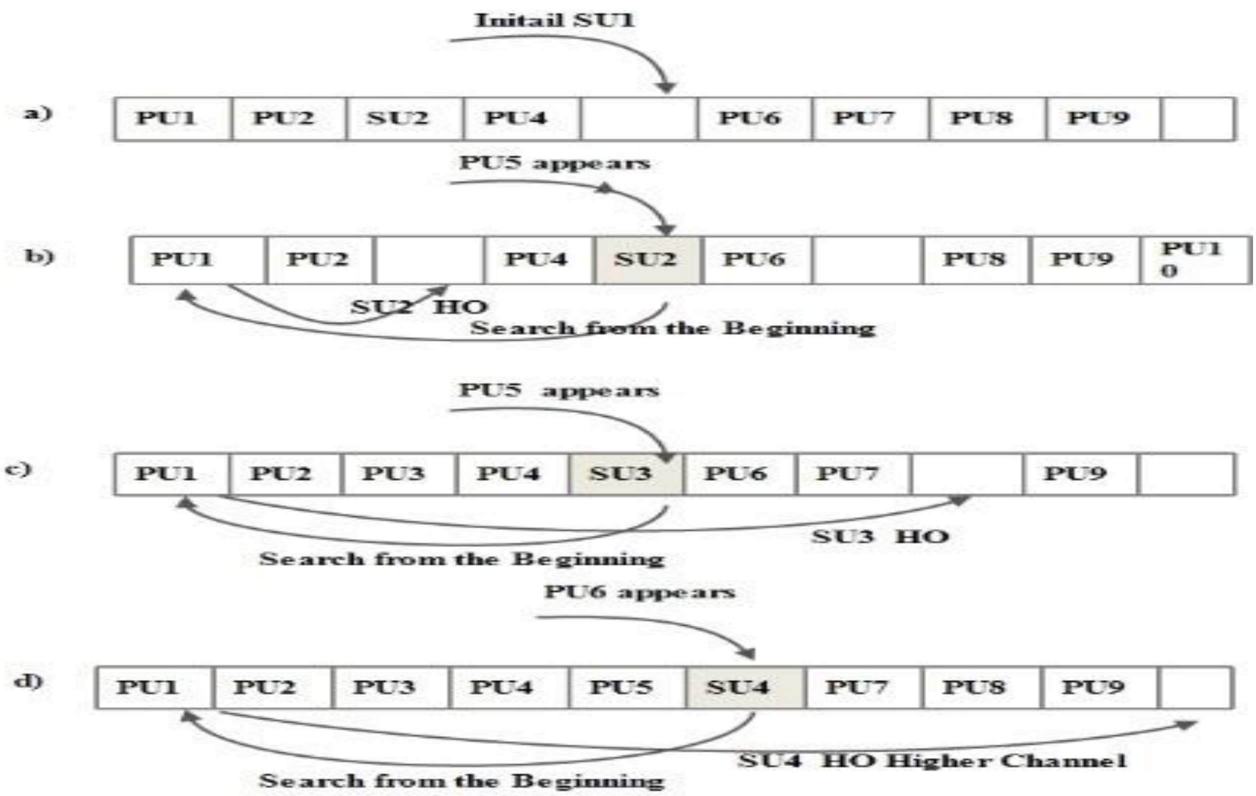


Figure 3.3: Spectrum Band (pool) Systematic Selection a) Initial state; b) Low to High; c) High to Low; d) QoS Highest HO (waste case for availability).

IV Performance and Simulation Results

In order to investigate the performance of the proposed scheme in this section, the system environment was based on many applications to reflect to real coverage area and environment, since the IEEE organization classified according to coverage area as well as network type into personal area network (PAN), local area network (LAN), metropolitan area network (MAN), and regional area network (RAN). We can categorize these standards based on cell size into small, medium, and large cells [11].

Based on criteria of TV White Space (TVWS) in the regulations[12,13] which are both regulatory organizations and stakeholders have been very focused on this band because it is an extremely valuable band in terms of propagation and in-building coverage . Each CR user is uniformly distributed in the cell is assumed, the intracell / intrapool type of handoff is adopted in our work simulation.

We obtained the updated holes of white space spectrum from the list of proactive prediction which is prepared by sensing function in CR system. Assume that the outage probability of SU is measured at the same power sensitivity of conventional real applications. Thus, the decision handoff is executed to avoid the dropping or breaking of link maintenance communication and enclose a more efficient

We present these applications as a case to evaluate the performance of the proposed system in the following subsections and comparing the performance with classic random selection scheme, and also we will study the impact of power adaptation technique.

Case: Medium Cell Application to CR

We considered characteristics of WiMAX [14] and LTE 700[15] as example applications from real environment in medium cell size, and simulation parameters are given in following Table 4.1.

Table 4.1 System parameters in medium cell size

Parameters	Fixed Wi-MAX	LTE 700
Available Frequency Range MHz	From 54 to 700 MHz (TV WS)	
Tx Power Adaptation (dBm)	36-40	40-42
Height hb (m)	18-30	18-30
Cell Size Coverage (km)	Up to 15	Up to15
number of User in Cell	50-150	50-150
Power sensitivity (dBm)	-107	-107
Channel Model	Okumora-	Okumora -Hata

	Hata	

Figure 4.1 and 4.2 show the performance gain of the proposed scheme using two application in medium cell size WiMAX and LTE in frequency range to note the impact frequency selection in this case.

Generally, the proposed systematic selection scheme improves the performance of wide frequency switching gain (spectrum handoff) for WiMAX and LTE up to 450MHz, 460 MHz respectively comparing with classic random scheme.

Comparing the gain of wide frequency for two applications WiMAX and LTE in this case and measured in all range of frequency, we show that the proposed systematic scheme is more efficient and can improve the switching range availability up to 64% from all range of frequency band.

V CONCLUSION

In summary, the expand in the frequency switching range at any frequency channel which operates currently in Base station (BS) in order to make a handoff process (low or high) is important because this expansion in the range permits the BS more flexibility to move to another frequency in the allowed range without having any of user out from boundary of the cell coverage area. This leads to maintain a suitable availability of the frequency channel to guarantee the success of spectrum handoff process.

The number of handoff as well as preventing the link communication from dropping becomes more efficient using the proposed scheme which enhances the overall performance of the CR system. Accordingly, the proposed scheme increases the wide of the frequency range by 64% approximately in both these applications as of cell coverage size .This ensures that the proposed scheme can be adopted in many applications and in different cell sizes and environments.

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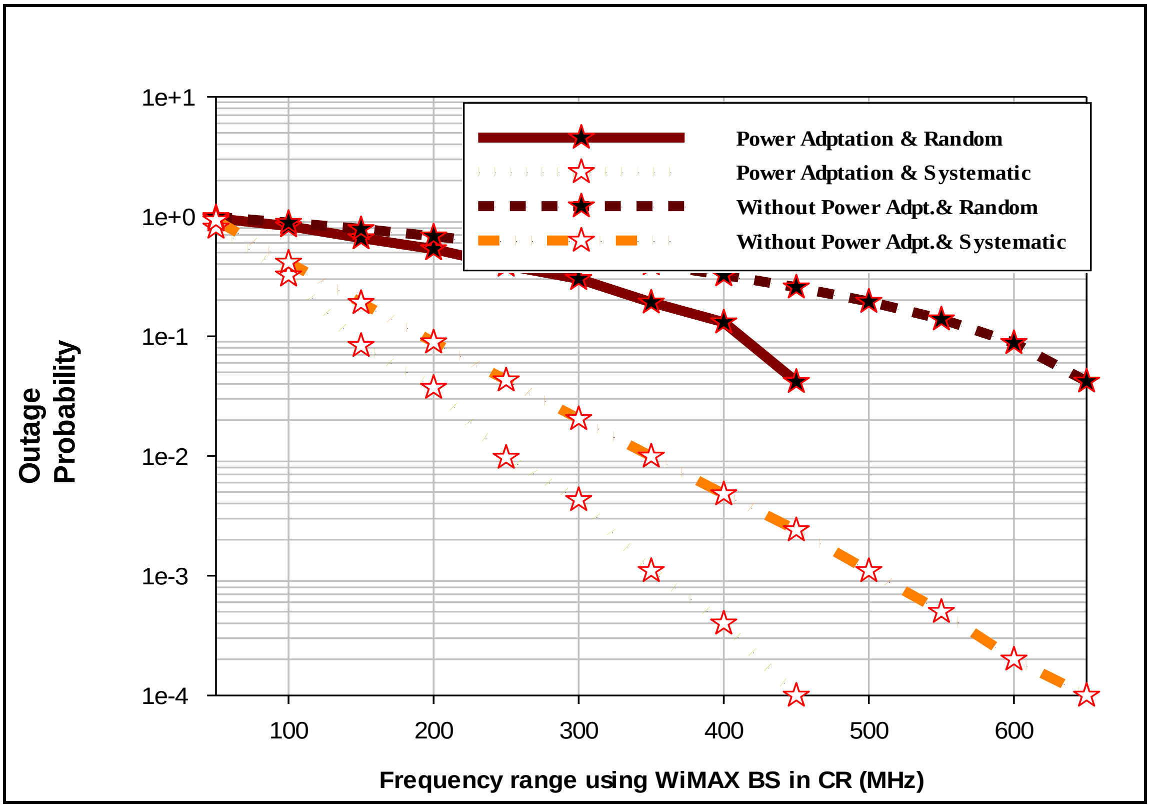

Figure 4.1: Outage probability of WiMAX CR application vs. TVWS frequency range.

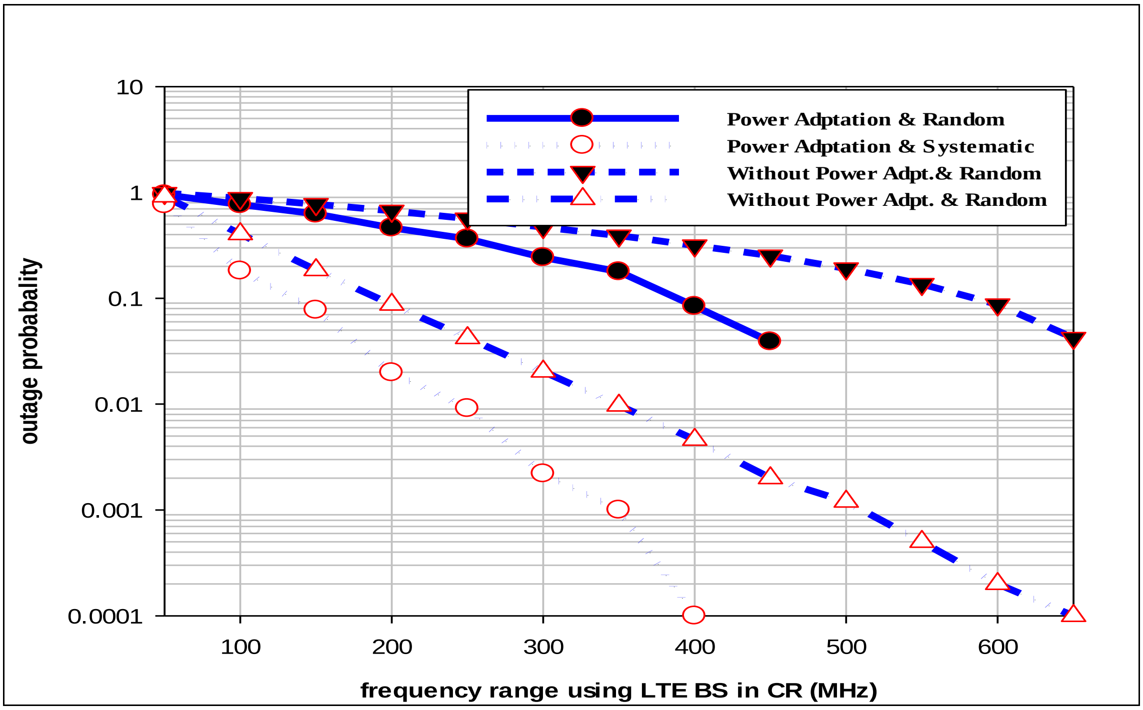

Figure 4.2: Outage probability of LTE700 CR application vs. TVWS frequency range.