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Single Layer Video Streaming Over Spectrum Underlay CR Networks

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ABSTRACT

Dynamic Spectrum Allocation (DSA) in Cognitive Radio (CR) will provide a chance to secondary users to opportunistically use a portion of spectrum, which actually belongs to primary users (PU). When primary users are not using their spectrum, it allows the secondary users to transmit their data. However, the issue that is to be discussed here is , SU transmission experiences interruption when the PU needs to use its spectrum. Hence, the objective of this paper is to provide Secondary user an uninterrupted multimedia data services (video transmission) by making it to receive data in underlay mode of CR. Here the base layer video streaming of a Scalable Video Coding (SVC) is a best solution for the underlay mode CR which is characterized by low data rate and low power. The download mode of video transmission is considered for underlay mode of SVC video transmission. Simulation results show the transmission of video in the underlay CR is a challenging task. However, acceptable video quality can be achieved with high protection of the base layer video of the SVC.

I. INTRODUCTION

Electromagnetic radio transmissions spectrums are with limited frequency band. Due to limited bandwidth and spectrum resource, it is extremely challenging to meet QoS requirements (ie., bandwidth, delay and quality requirements) for transmission over wireless networks. The limited wireless spectrum resource causes major delay problem for efficient multimedia transmission. However, according to an investigation of Federal Communications Commission (FCC) the assigned spectrum is not occupied all the time. FCC has published a report by designing new spectrum strategies to solve the overcrowded bands and allow secondary users to use licensed bands accordingly. The usage of spectrum is concentrated on certain portions of spectrum bands whereas considerable portion of spectrum remains unutilized. Hence, to improve the effective utilization of spectrum in real time and provide efficient communication the concept of Cognitive Radio technology is introduced.

II- RELATED WORK

Efficient spectrum utilization and spectrum sharing is achieved with Dynamic Spectrum Access (DSA), it has been observed that by using DSA the average spectrum utilization enhances from 15% to 85% [1] It has been reported in [1], that average spectrum utilization is from 15% to 85%. Hence we can consider that DSA enables Cognitive Radio [2]. Cognitive Radio allows the unlicensed secondary users to access the available spectrum when licensed primary user is not utilizing it. This procedure is known as Overlay in Cognitive Radio [3]. However the other way is, while the primary user is using its spectrum, the secondary user is allowed to use the same spectrum at low power levels, it is known as underlay in Cognitive Radio. The secondary user spreads its bandwidth to ensure fairly tolerable amount of interference to the primary user. CR technology ensures efficient utilization of available spectrum. Hence multimedia application which consume huge spectrum can be enhanced using these techniques.

Video transmission being a most widely used application, its transmission over CRN has gained great importance in the research community. Using the non-scalable video coding such as H.264/AVC and the scalable video coding (SVC) such as H.264/SVC, Video transmission over CR network can be realized. In [4] and [5], based on the feedback from the channel of CR for real time non- SVC video transmission expected video distortion of SU is minimized.

In [5], since the video distortion calculation that is performed at pixel level, the computation complexity may be high. Video quality in [6] is measured based on the smoothness of video playback, here buffer oriented channel allocation is considered. The usual Peak-Signal-to-Noise-ratio (PSNR) video quality is not measured in [6]. In [7], according to the channel condition for cognitive Ultra Wide Band (UWB), the video quantization parameter is changed. It may not be suitable for real time video coding applications, as it is a pre-process approach.

Using multicast, transmission of SVC video is discussed in [8]. Limiting of interference to primary users below a certain level and optimization of video transmission by measuring the proportional fairness among SU users is discussed here. For multi-hop CR [9] and in for femto cell CR [10] similar analysis is performed. Algorithms in [8] and [9] assumed that an acknowledgment is needed which may not be adopted in many multicast applications. In [11], to improve video quality under SVC video transmission, subcarrier, bit, and power allocation is performed for SU.

In this paper, scalable video transmission over CR network investigated. Dual modes of operation overlay mode and underlay mode of hybrid CR network is used in this study. The base layer of an SVC video is transmitted during underlay mode, and full layers, including base and enhancement layers of SVC video are transmitted during overlay mode. The SU needs to use low transmission power and low transmission rate in order to avoid interference to the PU and also it experiences interferences form both PUs and other SUs as well. The base layer of the SVC generally contains important information to be received by the SVC decoder and it's a basic and lowest video quality layer of SVC. With the help of base layer, the enhancement layers can be decoded. This layer is also related to low transmission power and low transmission rate. Hence, it is recommended to transmit this base layer of SVC during the underlay mode of a CR. However, this base layer needs to be highly protected using some error reduction schemes since there are chances of interferences form PUs and other SUs to these layers. The issues of the base layer transmission over underlay CR network are investigated in this paper.

III. VIDEO STREAMING TECHNOLOGY

Video streaming technology is one way to deliver video over the Internet. Using streaming technologies, the delivery of audio and video over the Internet can reach many millions of customer using their personal computers, PDAs, mobile smart phones or other streaming devices.

There are two major ways for the transmission of video/audio information over the Internet:

Download mode: The content file is completely downloaded and then played. This mode requires long downloading time for the whole content file and requires hard disk space.
Streaming mode: The content file is not required to be downloaded completely and it is playing while parts of the content are being received and decoded.

Streaming media may be either **real time** or **on demand**.

- **On Demand streams** are stored on the server and based on the user requirement content is transmitted. Then, user may play video or may download the video for viewing purpose.
- **Real Time stream** are only available on some particular time. For example, when the event is occurring and user can record the video.

IV. SYSTEM MODELS

The concept of overlay and underlay CR in the SVC video transmission is shown in Fig. 1. The unused spectrum region's which are licensed but is not currently being used is shown by grey region. Secondary Users operating in overlay mode CR uses this region to avoid interference to PU. The under used spectral regions are shown by black region, these are licensed but not being used to its full capacity. By introducing minimum interference to the PUs, SUs operating in underlay mode uses this region. The region below the threshold line is underused frequency spectrum. For high quality video performance for SU (overlay mode), all SVC layers including base layer needs to be transmitted in grey region. The base layer of the SVC is then transmitted in the black region for acceptable video performance for SU (underlay mode).
The SVC video streaming over the CR wireless network is shown in Fig. 2. The H.264/SVC can support spatial scalability, temporal scalability and quality scalability [13]. The devices that have multiple display resolutions such as mobile phone and smart phone, spatial scalability is important. Temporal scalability provides supports for different frame rates. Enhancement layer will be allowed truncated at any bit location with the help of Quality scalability. H264/SVC will encode the video once and many layers of video that can support spatial, temporal or quality scalability will be generated at the server. The PU and SUs are sharing the same channel. Initially, spectrum sensing is performed by SU and if free unoccupied channel is found, then all the scalable layers of SVC can be transmitted using overlay mode. In the next spectrum sensing process, if a PU is found, then the CR will switch to underlay mode and transmit the base layer only.

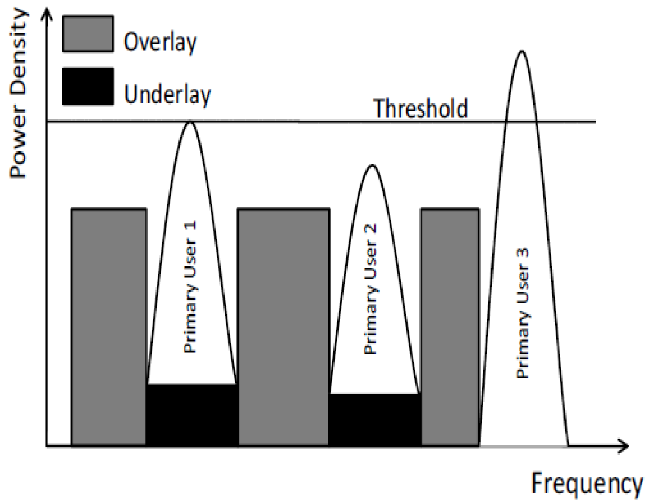

Fig-1: SVC video transmission in overlay and underlay CR.

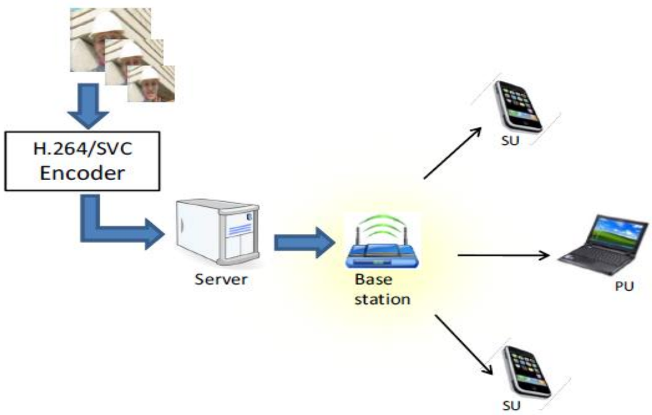

Fig-2: Scenario for the SVC video streaming

As the Streaming mode of video transmission requires large bandwidth as content file is not required to be downloaded completely and it is playing while parts of the content are being received and decoded, for this streaming process spectrum without interference is required. Hence overlay mode will be most suitable method. But On Demand streams are stored on the server and based on the user requirement content is transmitted. Then, user may play video or may download the video for viewing purpose. Here the proposed underlay mode will be considered for the SVC video transmission.

A. Underlay Model

The performance of underlay model for the SUs can also be represented using bit error rate (BER) expression. From [3], the Signal-to-Interference plus Noise (SINR) can be stated as,

$$SINR = \frac{N_f\ E_{b,s}}{\sum_{k=1}^{K} M_K\ E_{b,K}\ + N_f\ (\frac{N_o}{2})} \text{----------------1}$$

where N_f is the total number of subcarriers over the entire band, $E_{b,s}$ is the bit energy of the SU, is the total number of sub carriers occupied by PU, $E_{b,k}$ is the bit energy of the PU, and N0/2 is the noise contribution and k is the total number of PU. If all the PU have the same bit energy,

$$\sum_{k=1}^{K} M_K \; E_{b,K} \; = M \; E_{b,p} \qquad \text{------------------ } 2$$

where M is the total number of subcarriers occupied by PU. Hence, (1) can be written as,

$$SINR = \frac{N_f \; E_{b,s}}{M \; E_{b,p} + N_f \; (\frac{N_o}{2})}$$

$$= \frac{2E_{b,s}}{\frac{2M \; E_{b,p}}{N_f} + N_o}$$

$$= \frac{2}{\frac{2M}{N_f} (\frac{E_{b,p}}{E_{b,s}}) + \frac{N_o}{E_{b,s}}} \qquad \text{---------------------- } 3$$

Where ($E_{b,p}/E_{b,s}$) is the bit energy ratio of PU and SU and $N0/Eb,s$ is the reciprocal of the SNR. Hence, the BER performance in the underlay model is,

$$P(e)_{underlay} = Q \; (\sqrt{SINR})$$

$$= Q\left(\sqrt{\frac{2}{\frac{2M}{N_f} (\frac{E_{b,p}}{E_{b,s}}) + \frac{N_o}{E_{b,s}}}}\right) \qquad \text{------------- } 4$$

From (4), the packet error rate (PER) for underlay CR can be calculated as,

$$\text{PER}_{\text{underlay}} = 1-(1-P(e)_{\text{underlay}})^{L} \qquad \text{---------------------}5$$

where *L* is the packet size in bits. The PER is obtained following the approach in [12]. It is assumed in this work that the packet here is the video packet. For typical video application Quality of Service (QoS) [14], the PER should be less than 0.01 or 1%. If the PER is less than 1%, the video packet will be dropped at the SVC video decoder side and will be concealed using an error concealment technique.

V. THEORETICAL AND SIMULATION RESULTS

As per the approach discussed in [3], using multi carrier modulations such as MC-CDMA and OFDM the underlay CR modes can be realized. The SU is modelled as MC-CDMA with BPSK. Modulation .The PU is modelled as OFDM with BPSK modulation using a contiguous N = 32 subcarrier spectrum. . Here, one PU and one SU is assumed in the simulations.

The theoretical results are based on AWGN channel and the packet size L = 1000 bits. Figure 3 shows the theoretical performance for underlay CR mode for SU using (4). The PER underlay from (5) is also shown in the figure. The theoretical result in figure is plotted using the "qfunc" function in the MATLAB. The line with square shows the performance of the SU in underlay mode with Nf = 1024. The PER underlay in Fig. 4 is generated from the line with square. Based on these theoretical results, the theoretical PER for underlay is generated for random numbers at $Eb/N0$ = 13 dB. It is assumed that the simulation results will follow closely the theoretical results as discussed in [3]. The packet in this case is assumed to be the video packet. The video packet will be dropped if the PER is less than the video QoS, which is 1%.

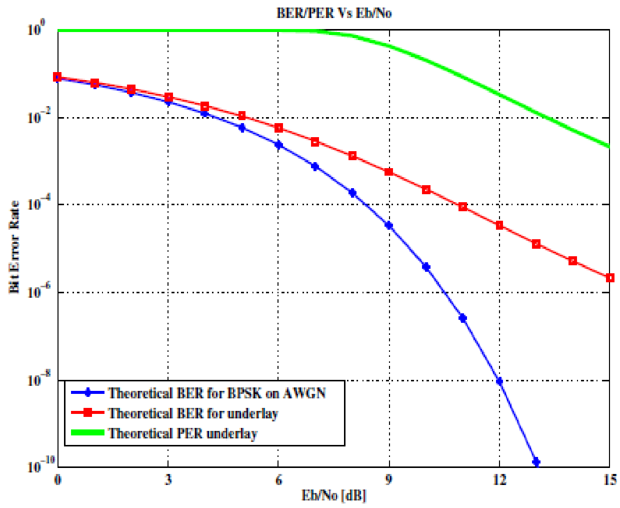

Fig. 3: BER and PER performance for SU in underlay CR.

We performed the video simulation and the H.264/SVC codec [15] is used to code and decode the video sequence. The main simulation parameters for SVC are shown in Table I. In the simulation, quality scalability of the SVC is used. For simplicity, it is assumed that the base layer (layer 0) has lower video quality than the enhancement layer (layer 1). Table II shows the bit rates and luminance (Y) PNSR results of encoding the video sequence Foreman using the SVC with I-frames inserted every 15 frames. Layer 0 and layer 1 are quantized using the quantization parameter (QP) of 30 and 25 respectively. I-frames stand for intra-coded picture that are compressed using JPEG like compression without referring to other frames. P-frames are frames that are predicted from previous frames and contain only the changes from the previous frame. I-frames are used as reference and can be used to stop error propagation from P-frames.

Parameters	Value
Input Video	Foreman cif.yuv
Video Width	352
Video Height	288
Quantization	30 for layer 0 (base layer), 25 for layer 1 (enhancement layer)
Frame format	IPPP
No. of I frames	Varies

TABLE I: SVC Parameters

It is assumed that the transceiver during overlay and underlay transmission is available at the base station. The decision to switch between overlay and underlay mode is influenced by sensing results from SU. When the CR network is operating in overlay mode, the base layer and the enhancement layer of the SVC are streamed to SU.

When the CR network is operating in underlay mode, only the base layer is streamed to the SU. The video packet in underlay mode is subjected to PER underlay in (5). From the simulation, the video packet error rate is about 20%. This high packet error rate is due to the interference from PU and other SU. Numbers of I-frames are increased to mitigate the effect of video packet loss in the underlay mode. Table II shows results improvement when more I-frames are used during the encoding.

The subjective video quality for foreman video sequence for I-frames insertion of every 30 P-frames, 15 P-frames, 10 P-frames and 5 P-frames are shown in Fig. 5(a), 5(b), 5(c) and 5(d), respectively. It shows a significant improvement when more I frames are used but at the cost of higher bit rates as shown in Table II. The last row in Table II shows that for every 5 P-frames, one I-frame is inserted to reduce propagation errors. The propagation of errors can be seen in Fig. 5(a) and Fig. 5(b). Usage of I-frames to increase error resiliency has been known in the video coding community [16]. Although, more I-frames have been used, the PSNR is still below 30 dB. The reason is due to the high packet loss in the underlay mode CR that comes from the interferences of PU and other SU. It is to be noted that no channel coding is used in the simulation to mitigate the packet error. Only basic error resilience technique, namely the insertion of I-frames is used. To improve the video performance, other techniques of error resilience such as Flexible Macro-block Ordering (FMO) and multiple descriptions coding (MDC) can be used. Forward Error Correction (FEC) at the MAC layer can also be used to mitigate the effect of BER at the physical layer [16].The overlay and underlay framework in frequency selective fading channel is investigated in [17].

(a) Every 30 P-frames **(b) Every 15 P-frames**

(c) Every 10 P-frames **(d) Every 5 P-frames**

Fig. 5: Subjective quality of video streaming using underlay CR for I-frame insertion

Frequency of I-frames, every	Bit Rates Original (kbps)	PSNR Original (dB)	PSNR Underlay (dB)
30 frames	404	36.21	22.05
15 frames	445	36.28	23.90
10 frames	476	36.34	27.12
5 frames	586	36.44	29.33

TABLE II: SVC Results in Underlay CR

VI. CONCLUSION

In this paper, the problem of video streaming using SVC in underlay mode of wireless CR is observed to allow uninterrupted multimedia services to the SU. Video streaming to the SU in the overlay mode is not a problem as long as the frequency spectrum resulting from the spectrum sensing is available. However, in the underlay mode, interferences from PU and other SU results in video packet loss to the existing SU. Here on demand mode of video transmission is considered for underlay mode of SVC transmission. Hence, some form of error resilience need to be embedded during the scalable video encoding process. In this paper, I-frames insertion is used as the error resilience technique to mitigate the packet losses in the underlay CR. Simulation results shows PSNR improvement of 7 dB by inserting one I-frame for every 5 P-frames compared to one I-frame for every 30 P-frames. Future works include using channel coding to improve BER performance at the physical layer and using other video error resilience techniques at the application/video layer.

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