Interoprability Between Video Frames and Available Spectrum Bands in Cognitive Radio Networks

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Abstract

We aim to provide uninterrupted video streaming over CRNs with the objective of maximizing video quality to achieve fairness among the concurrent video frames, subject to mitigated interference to the incumbents. Our contribution is to make an interoperability between the priority of the frames and the quality of available bands. Our proposed method is content-context-aware and network-context-aware, in which the user analysis the both the content and the quality of available bands. Then based on the quality of available channel, it transmits the frames according to their quality over the channels with higher quality and so on. Our simulation results prove the superiority of the proposed framework in terms of received video quality.

1. INTRODUCTION

Regarding an ever increasing solicitation for high data rates, coupled with increasing of bandwidth hungry multimedia applications, the issue of spectrum availability became an obstacle on the way of wireless communication advancements. With a cursory glance at the traditional spectrum allocation chart, it may be believed that spectrum is a scarce commodity. However, according to the results of spectrum occupancy measurement by Share Spectrum Company [1], in most of the places many portions of the spectrum bands remain unused in adequate periods of time. Frequency agility in Cognitive Radio (CR) makes it as a promising technology to alleviate the issue of spectrum scarcity. In CR networks (CRNs), a CR-equipped user has the capability to periodically sense and identifies available channels where there is no active Primary User (PU), and try to occupy those portions for its transmissions [2]. According to loss tolerant and rate adaption of video files, and variation of the quality of available spectrum bands, by making an interoperability between video frames priority and quality of available bands, graceful degradation of QoE can be achieved [3].

In this paper, we investigate the problem of video streaming over multiple channels using CR technology in order to maximize the overall video quality subject to mitigated interference to the incumbents. In Fine Granularity Scalability (FGS), a video file is encoded into one base layer and one or more enhancement layers. The base layer represents the basic or the lowest video quality with low transmission rate and low transmission power. The base layer composed of some frames i.e. I-frame, P-frame and B-frame. The enhancement layers are for enhancing to quality of video. In a descending fashion, the priority is first to the I-frames, P-frames, B-frames and then enhancement layer frames.

On the other side, there will be a ranking list of available spectrum bands based on their characteristics such as bitrate. The list is reported to CR-user through a common control channel. Then, the user decides to transmit the frames over multiple channels based on their priority simultaneously. We formulate streaming separate video frames over multi channels with respect to spectrum sensing and sensing errors, spectrum access and interference mitigation, and QoE.

2. SYSTEM FRAMEWORK

In the proposed framework, the CR-users cooperatively sense the availability of spectrum bands and report to a central entity in order to control spectrum access. When a node is going to transmit multimedia content, first it requests for the ranked list of available spectrum bands. Upon receiving the list, it maps the frames over different channels with respect to their priority. Thus, each user needs to have two transceivers, one for exchange channel information with the central entity and the other one for channel sensing. The spectrum band is assumed to have several orthogonal channels with different bitrate [4].

The users periodically opt a channel to sense in each time slot and the result of their sensing will be reported to the central entity. There will be two types of sensing error i.e. false alarm and miss detection [5]. False alarm error results in wastage of a spectrum while miss detection leads to interference to the Pus [6]. The conditional probability that a channel is available is based on a specific sensing result done by the users independent of sensing history.

$$\begin{cases} Presence\ of\ Signal\ if\ (\sum_N (R_s[n])^2) > \lambda \\ Absence\ of\ sginal\ if\ (\sum_N (R_s[n])^2) < \lambda \end{cases} \quad (1)$$

$$P_{detection} = P\{(\textstyle\sum_N (R_s[n])^2) > \lambda | H_1\} = Q_M\left(\sqrt{2SNR}, \sqrt{\lambda}\right) \quad (2)$$

$$P_{False_{alarm}} = P\{(\textstyle\sum_N (R_s[n])^2) > \lambda | H_0\} = \frac{\Gamma\left(m, \frac{\lambda}{2}\right)}{\Gamma(m)} \quad (3)$$

$$P_{detection} = Q\left(\frac{1}{\sqrt{2SNR+1}}\left(Q^{-1}\left(P_{False\_alarm}\right) - \sqrt{N.SNR}\right)\right) \quad (4)$$

where R_s is the received signal, N is number of samples, SNR is signal-to-noise ratio, and M is the Marcum Q-function factor. From the above-stated probability function of false alarm it can be observed that P_{False_alarm} is independent of SNR [7,8], hence, under H_0 it means the presence of the PU. The fading environment under Rayleigh fading, the result of $P_{detection}$ function will be the probability of detection given instantaneous SNR, thus probability of PU detection is;

$$P_{detection} = e^{-\frac{\lambda}{2}} \sum_{k=0}^{m-2} \frac{1}{k!}\left(\frac{\lambda}{2}\right)^2 + \left(\frac{1+SNR}{SNR}\right)^{m-1} \times \left(e^{\frac{\lambda}{2(1+SNR)}} - e^{-\frac{\lambda}{e}} \sum_{k=0}^{m-2} \left(\frac{\lambda SNR}{2(1+SNR)}\right)^k\right) \quad (5)$$

For different channels the probability of interference to the PUs can be calculated as:

$$\mathrm{P(Chann\_Avail\ |\ Chann\_Busy)} = \sum_{i \in N} \binom{N}{i} (1 - P_{miss})^{N-i} (P_{miss})^i \quad (6)$$

In FGS [4] the video is encoded in one base layer and one or more enhancement layers. The total bitrate for the content is equal to:

$$R_C = R_B + R_E \quad (7)$$

where

$$R_B = R_{IF} + R_{PF} + R_{BF} \quad (8)$$

The average PSNR of the content is:

$$\Psi_C = \Psi_B + \alpha\ (R_C - R_B) \quad (9)$$

where Ψ_B is the PSNR when the base layer is decoded independently, and α is a constant depending on video sequence and setting of the codec. The packet volume assumed to be fixed, the average rate will be $(S_p V_p)/(A.T_S)$, where S_P is sum of the received packets, V_P is the packet volume, A is the number of time slots, and T_S is the time slot duration.

3. Simulation Results

For simulation, we assumed three primary networks and nine channels. We assume fixed packet length be equal to 100, time slot duration be 0.03, and 20 time slots. The channel utilization is assumed to be 0.5. Probability of false alarm and miss detection are selected 0.25 and 0.15 respectively. Furthermore, the maximum interference to the PUs is set to be 0.25. The video content is in Common Intermediate Format (CIF, 352, 288) with frame rate equals to 30 fps and a GOP consists of 10 frames.

Figure 1 shows the probability of detection versus the probability of false alarm with different SNR values e.g. 1, 2, and 3 dB. As illustrated by the figure, when the probability of false alarm increases the probability of is increased, it is because of the correlation between two probabilities. The impact of spectrum sensing error is shown in Figure 2. Five sensing error combinations have been examined and the average PSNR has been plotted. We compared our proposed method with regular CR network scenario. It can have been seen that the proposed method has better performance when the false alarm probability is between 0.2 and 0.3.

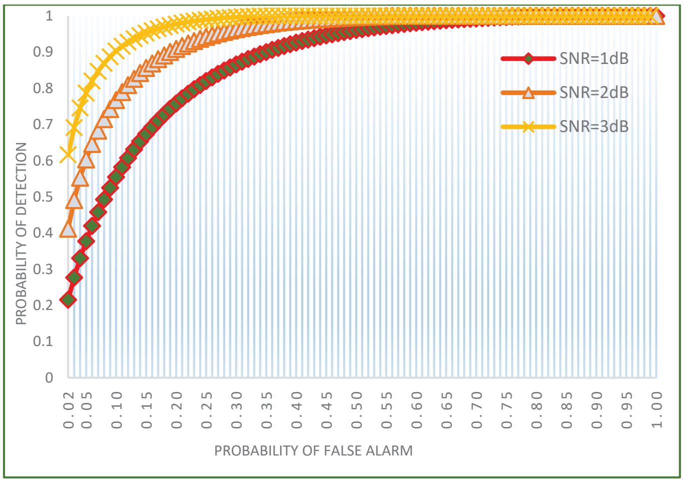

Fig. 1. Probability of PU detection vs. probability of false alarm with different SNR values.

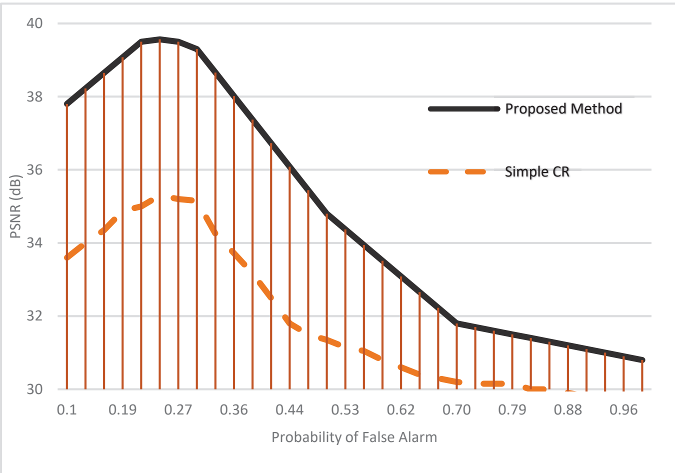

Fig. 2. Video PSNR vs. probability of False Alarm

4. Conclusion

This paper proposes an efficient method which makes an interoperability between the priority of video frames and quality of available spectrum bands in order to achieve high quality video and QoE. The proposed system tries to sense the available spectrum bands by CR users and report the sensing result to a central entity. Then when a node aims to send video file, the ranked list of the available spectrum bands will be sent to the node by the central entity. Based on the priority of the video frames, the nodes transmit high priority frames over high quality spectrum bands. Our simulation results prove the efficiency of the proposed method in terms of high quality and QoE.

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