Estimation of Probability of Missed Detection using a Collaborative Approach for TV Signals under Cognitive Radio Network

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ABSTRACT
Spectrum Sensing is an essential part of Cognitive Radio. Spectrum can be sensed by numerous algorithms. Energy Based can easily detect presence of signal and cyclostationary based detection can easily detect signals at low SNR. We havecollaborated the two algorithms resulting in a Collaborative Approach. In addition to that a feature based detection has been used for calculating the probability of missed detection of TV signals at low SNR.

In this paper we have sensed the TV signals as well as the probability of missed detection for both are calculated. Collaborative approach efficiently detects the TV signals utilizing the concept of threshold energy and differentiating noise form original signal. Feature detection calculates on the basis of extraction of spectral features of TV signals. Simulation results show that the proposed sensing technique can reliably detect analog and digital TV signals at low SNR.

Index Terms
Spectrum Sensing, Congnitive Radio, Missed Detection, Feature Detection.

1. INTRODUCTION
The underutilization of spectrum even though much of them are allocated.to licensed users still only about 30% of the spectrum is utilized while the rest are unused. Although spectrum is allocated to a primary user they are virtually not used and with a rapid growth in the area of cognitive radio the spectrum can be utilized more efficiently.

The Federal Communications Commission (FCC) has recently opened the TV bands for cognitive radio devices, which can continuously sense the spectral environment, dynamically identify unused spectral segments, and then operate in these white spaces without causing harmful interference to the incumbent communication services.

In its most basic form, CR is a hybrid technology involving software defined radio (SDR) as applied to spread spectrum communications. Possible functions of cognitive radio include the ability of a transceiver to determine its geographic location, identify and authorize its user, encrypt or decrypt signals, sense neighbouring wireless devices in operation, and adjust output power and modulation characteristics[4].

Spectrum sensing is the process of periodically and dynamically monitoring a given radio spectrum band (e.g., VHF and UHF TV bands) in order to determine its availability for use on a non-interfering basis. Spectrum sensing is a mandatory functionality in any CR-based wireless system that shares spectrum bands with primary services, such as the IEEE 802.22 standard, which proposes to reuse vacant spectrum in the TV broadcast bands.

In this paper, we develop a collaborative and feature detection-based spectrum sensing technique for a single CR to meet the FCC sensing requirement. The basic strategy is to correlate the period gram of the received signal with the selected spectral features of a particular TV transmission scheme, either the national television system committee (NTSC) scheme or the advanced television standard committee (ATSC) scheme, and then to estimate the probability of missed detection for both schemes. By estimating the probability we can further handle the large bandwidth more effectively. The two approaches are simultaneously used for spectrum sensing as well as estimating missed detection. Simulations have been carried out for low SNR values more precisely less than -20db to show the effectiveness of spectrum sensing in presence of additive white Gaussian noise (AWGN).

2. FEATURES OF TV SIGNALS
TV channel occupies a total bandwidth of 6 MHz and its power spectrum density (PSD) describes how the signal power is distributed in the frequency domain. NTSC is the standardized analog video system used in North America and most of South America. The power spectrum of an NTSC signal consists of three peaks across the 6 MHz channel, which correspond to the video, color, and audio carriers, respectively.

On the other hand, ATSC is designed for the digital television (DTV) transmission, and it delivers a Moving Picture Experts

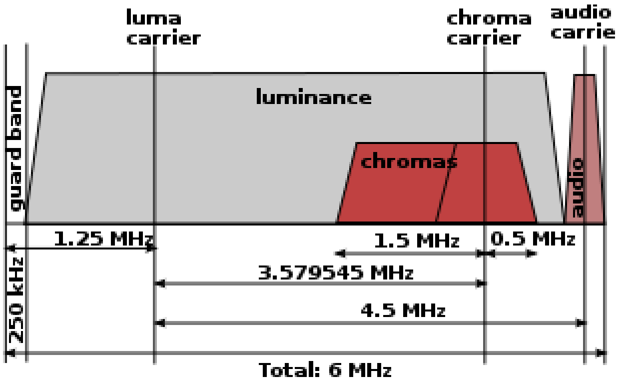
Group (MPEG)-2 video stream of up to 19.39 Mbps. The

ATSC spectrum is relatively flat but has a pilot located in 310 kHz above the lower edge of the channel.

The NTSC signal was advanced by the ATSC signal and the analog system was completely digitized by ATSC signal.

A. National Television System Committee (NTSC)
The first NTSC standard was developed in 1941 and had no provision for color television. In 1953 a second modified version of the NTSC standard was adopted, which allowed color television broadcasting compatible with the existing stock of black-and-white receivers. NTSC was the first widely

adopted broadcast color system and remained dominant where it had been adopted until the first decade of the 21st century, when it was replaced with digital ATSC. NTSC baseband video signals are also still often used in video playback (typically of recordings from existing libraries using existing equipment) and in CCTV and surveillance video systems.



B. Advanced Television System Committee (ATSC)

ATSC standards are a set of standards developed by the Advanced Television Systems Committee for digital television transmission over terrestrial, cable, and satellite networks.

The ATSC standards were developed in the early 1990s by the Grand Alliance, a consortium of electronics and telecommunications companies that assembled to develop a specification for what is now known as HDTV. ATSC formats also include standard-definition formats, although initially only HDTV services were launched in the digital format. The high definition television standards defined by the ATSC produce wide screen 16:9 image up to 1920×1080 pixels in size more than six times the display resolution of the earlier standard.

However, many different image sizes are also supported. The reduced bandwidth requirements of lower-resolution images allow up to six standard-definition "sub channels" to be broadcast on a single 6 MHz TV channel.

3. SPECTRUM SENSING

Spectrum Sensing is mainly done after the spectral features priori known at the receiver end. The spectral features of NTSC and ATSC signals are known at the receiver end before the spectrum sensing on the signals are done.

The strategy used for sensing is a combination of energy and cyclostationary based detection together known as a collaborative approach. Energy detection easily detects the presence of white space and the cyclostationary based detection helps in differentiating between a false alarm and the original signal [11]. As computational complexities are added by the cyclostationary detection at low SNR feature detection compensates for those complexities.

- H_0 : (primary user absent)

  $y(n) = u(n)\ n = 1, 2, \ldots, N$ (1)

- H_1 : (primary user present)

  $y(n) = s(n) + u(n)\ n = 1, 2, \ldots, N$

Where u (n) is noise and s (n) is the primary user signal.

At the end of the above diagram the threshold decision block shown and its decision has been made on the base of two hypotheses are related to the detection of primary user signals, first one is null hypothesis $H0$ and the alternative hypothesis $H1$.$H0$ is the case in which a primary user signal is not present in primary spectrum, and $H1$ describe the case in which a primary signal is available. And by measuring the energy it will estimate which hypothesis is more credible and to decide whether $H0$ or $H1$ is correct which is main purpose of energy detection. In energy detection we have two general performance matrices which are used to evaluate the performance of energy detector.

The probability of detection $\boldsymbol{P_d}$:

$$P_d = P_r\,(Y > \lambda/H_1) = Q_u\left(\sqrt{2\gamma}, \sqrt{\lambda}\right)$$

The probability of false alarm $\boldsymbol{P_f}$:

$$P_f = P_r\,(Y > \lambda/H_0) = \frac{\Gamma\left(u, \frac{\lambda}{2}\right)}{\Gamma(u)}$$

Another hypothesis taken for the probability of missed detection considered by feature detection where the spectral feature is priori known at the receivers end.

$H_0 : y(l) = v(l)$

$H_1 : y(l) = x(l) + v(l)$

where ; y(l) = received signal by a secondary user.

v(l) = complex zero mean white Gaussian noise

x(l) = transmitted incumbent signal

Then we convert the following signals into its power spectral density

H0: Sy ω = σv2

H1: Sy ω = Sx ω + σv2

where, Sx ω = PSD function of primary signal

The Fourier transform of the received signal is prior known at the receiver

Sy (n) .(k) , k=0,1,.....,n-1

The PSD of the received signal is given by the following equation

Sx(n).(k)= Sx($2\pi k/n$)

The final output given to the comparator is given below by the equation and compared with the threshold value given to comparator

$$Tn = \frac{1}{n}\sum_{k=0}^{n-1} Sy(n)(k)Sx(n)(k) <=> \lambda$$

λ = threshold decision.

If $Sx(n) > \lambda$

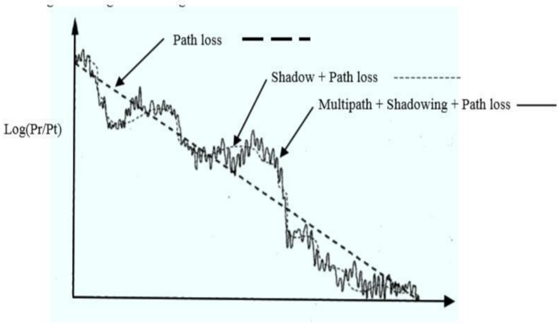
then H1 hypothesis is correct.

$Sx(n)(k)\ Sx(n)(k) < \lambda$

then H0 hypothesis is correct.

3.1 Noise

Noise is the most important parameter that acts as a hindrance in spectrum sensing. Any transmitted signal is primarily affected by various types of noise.



Log(d)

Fig1. Causes of Noise

There are four types of losses that affects the power of the signal. The graph above shows the losses and its effect in the channel. The thick dashed line represents the path loss. The lognormal shadowing changes the total loss to that shown by the thin dashed line. The multipath finally results in variations shown by the solid thick line. Note that signal strength variations due to multipath change at distances in the range of the signal wavelength.

Path Loss: The simplest channel is the free space line of sight channel Communication with no objects between the receiver and the transmitter or around the path between them. The loss of power in the path is known as path loss[6].

Shadowing: If there are any objects (such buildings or trees) along the path of the signal, some part of the transmitted signal is lost through absorption, reflection, scattering, and diffraction. This effect is called shadowing.[6]

Multipath: The objects located around the path of the wireless signal reflect the signal. Some of these reflected waves are also received at the receiver. Since each of these reflected signals takes a different path, it has a different amplitude and phase. Depending upon the phase, these multiple signals may result in increased or decreased received power at the receiver. Even a slight change in position may result in a significant difference in phases of the signals and so in the total received power.[6]

3.2 Awgn Noise

Additive white Gaussian noise (AWGN) is a channel model in which the only impairment to communication is a linear addition of wideband or white noise with a constant spectral density (expressed as watts per hertz of bandwidth) and a Gaussian distribution of amplitude. The model does not account for fading, frequency selectivity, interference, nonlinearity or dispersion. However, it produces simple and tractable mathematical models which are useful for gaining insight into the underlying behavior of a system before these other phenomena are considered.

3.3 ITU Channel

The International Telecommunication Union, originally founded as the International Telegraph Union, is a specialized agency of the United Nations that is responsible for issues that concern information and communication technologies. For the multipath fading channel model, we apply the ITU Pedestrian B model, whose power Delay profile is given in Table I. The root mean square (RMS)delay spread of the ITU Ped-B model is 633 ns.

Table1.1 . ITU CHANNEL

Delay(ns)	0	200	800	1200	2300	3700
Gain (dB)	0	-0.9	-4.7	-8.0	-7.8	-23.9

4. SIMULATION RESULTS

As explained the paper revolves around spectrum sensing and probability of missed detection for low SNR values 20dB. Our goal is to show the probability of missed detection at low SNR for various noise channel to be more confined for AWGN and ITU channel. Complete 6 MHz bandwidth is considered for simulation purpose. Apart from bandwidth other important simulation parameters such as sampling frequency, bitrate, carrier frequency is taken into account.

The simulation process has taken into account real time transmission parameters. For simulating, a complete virtual environment has been created by taking into account the pilot insertion, noise addition etc. which makes the simulation environment much more similar to the real world communication.

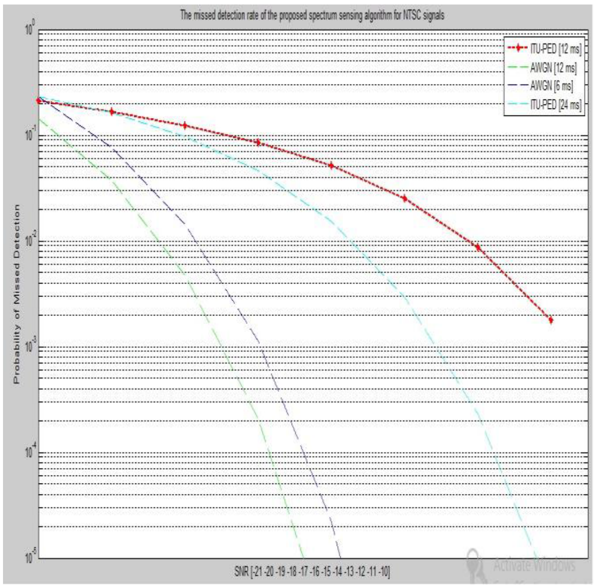


Fig 2.The missed detection rate proposed spectrum for NTSC signal inAWGN and ITU channel at various time intervals

The above graph shows the probability of missed detection and SNR in case of two channels namely AWGN and ITU. The graph is plotted for mainly 6,12 and 24ms time slots for ITU and AWGN channels for NTSC signal.

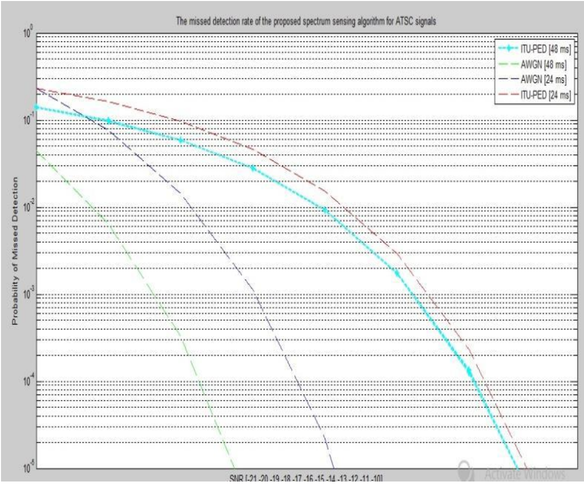


Fig 3 .The missed detection rate proposed spectrum for NTSC signal in AWGN and ITU channel at various time intervals

The above graph shows the probability of missed detection and SNR in case of two channels namely AWGN and ITU. The graph is plotted for mainly 24 and 48ms time slots for ITU and AWGN channels for ATSC signal.

Simulation results show that the proposed spectral feature correlation detector can reliably detect analog and digital TV signals at SNR as low as −20 dB.

5. CONCLUSION

In this paper we have estimated the probability of missed detection for two channel models. The probability of missed detection at low SNR is easier and simpler in case of AWGN noise channel compared to ITU channel. The more the number of spectral features in a TV signal more prominent is the missed detection of the signal. The probability of missed detection for NTSC signal is better compared to ATSC signal as it has three peaks. The simulation results shows the above stated conclusions.

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