Channel State Estimation in Cognitive Radio System Using Energy Detection Scheme

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***Abstract*- Recently, spectrum sensing and channel estimation has been intensively studied as a key technology in realizing the cognitive radio. Many researchers and scientists has worked upon it and presented multiple techniques, to improve the performance of spectrum sensing and channel estimation. After a deep study we have seen that for implementation of CR System, any transceiver's Energy Detection unit can be used and that would be much efficient and reliable. We have worked upon energy detection schemes, to measure these attributes use of Region Of Curvature has been proposed by us. In this paper, we have discussed various aspects of Cognitive radio systems, after which we have proposed the channel estimation based on Energy detection, in which the un-utilized channels and utilized channels are compared and discriminated based on their energy levels on real time basis. Then we have given the code summary and simulation results for our proposed work.**

***Keywords* — Cognitive Radio, Primary User, Secondary User, False Alarm, Missed detection.**

I. INTRODUCTION

Due to immense growth of the wireless access communication technologies, required more and more spectrum resources following the conventional spectrum band, where most of the spectrum bands are exclusively allocated to the licensed services. Our studies shown that the spectrum wastage and creates artificial spectrum scarcity occurs because a lot of licensed bands are under-utilized. This suggests that the solution to the problem is to use dynamic spectrum access methodologies instead of static spectrum allocation policies to. This can be accomplished through the use of Cognitive Radio Technology.

Cognitive Radio is the emerging concept which follows the process of dynamic spectrum management, which is an intelligent radio that can be programmed and configured dynamically. It is capable of altering its reception or transmission parameters in accordance to the radio environment and the network state to use the available spectrum in optimal manner. Its transceiver is designed to use the best wireless channels in its vicinity. In which a radio automatically detects available channels in wireless spectrum, then accordingly changes its reception or transmission parameters to allow more concurrent wireless communications in a given spectrum band at one location. So many scientists and researchers worked upon this area and presented & proposed so many different types of techniques. We have also worked upon this area and found that any transceiver's energy detection unit can work more efficiently to showcase the efficient use of available radio frequency spectrum.

II. PROPOSED METHODOLOGY

1. Before showing our proposed methodology we would like to show two presumptions which we have used are as:-

- False alarm-->false indication of its presence
- Missed detection- Nothing would get register even though it is present.

We have developed following programs which we have used for energy detection scheme using matlab.

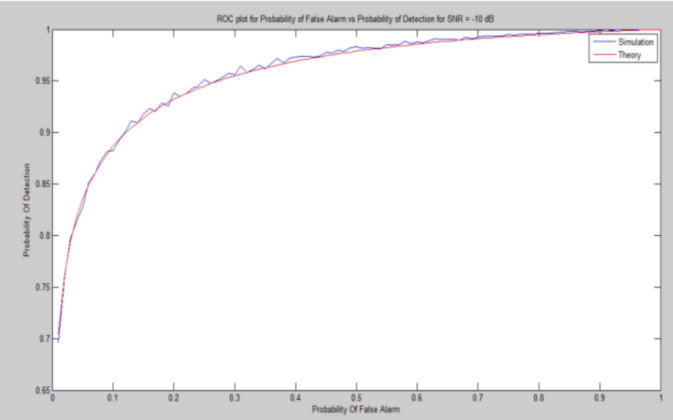
Program 1:-

Description - To look for probability of false alarm versus probability of detection graph, which is generated at -10dB for Gaussian signal with White real Gaussian noise. We can check for all energy statistics and if the energy is greater than the theoretical calculated value (threshold) then probability increases. This curve mirror reliability of energy detection unit.

Program -

```
% Plotting Receiver Operating
Characteristic curve for energy
% detection, when the primary signal
is real Gaussian signal and noise is
% addive white real Gaussian. Where,
the threshold is available
% analytically.

clc
close all
clear all
GraphicalPoint = 1000;
snr_in_dB = -10; % SNR in decibels
snr = 10.^(snr_in_dB./10); % Linear
Value of SNR
Pf_A = 0.01:0.01:1; % Pf_A =
Probability of False Alarm
%% Simulation to plot Probability of
Detection (Pd) vs. Probability of
False Alarm (Pf_A)
for m = 1:length(Pf_A)
    m
    i = 0;
for num_MonteCarlo_sim=1:10000 %
Number of Monte Carlo Simulations
 noise = randn(1,GraphicalPoint);
%AWGN noise with mean 0 and variance 1
 signal =
sqrt(snr).*randn(1,GraphicalPoint); %
Real valued Gauissian Primary User
Signal
 recieved_sig_at_SU = signal + noise;
% Received signal at SU
 energy = abs(recieved_sig_at_SU).^2;
% Energy of received signal over N
samples
 energy_fin
=(1/GraphicalPoint).*sum(energy); %
Test Statistic for the energy
detection
 thresh(m) =
(qfuncinv(Pf_A(m))./sqrt(GraphicalPoin
t))+ 1; % Theoretical value of
Threshold
 if(energy_fin >= thresh(m))  % Check
whether the received energy is greater
than threshold, if so, increment Pd
(Probability of detection) counter by
1
     i = i+1;
 end
end
Pd(m) = i/num_MonteCarlo_sim;
end
plot(Pf_A, Pd)
hold on
%% Theroretical expression of
Probability of Detection; refer above
reference.
thresh =
(qfuncinv(Pf_A)./sqrt(GraphicalPoint))
+ 1;
Pd_the = qfunc(((thresh - (snr +
1)).*sqrt(GraphicalPoint))./(sqrt(2).*
(snr + 1)));
plot(Pf_A, Pd_the, 'r')
title('ROC plot for Probability of
False Alarm vs Probability of
Detection for SNR = -10 dB');
xlabel('Probability Of False Alarm');
ylabel('Probability Of Detection');
legend('Simulation','Theory');
hold on
```

Simulation Result:-



Program 2:-

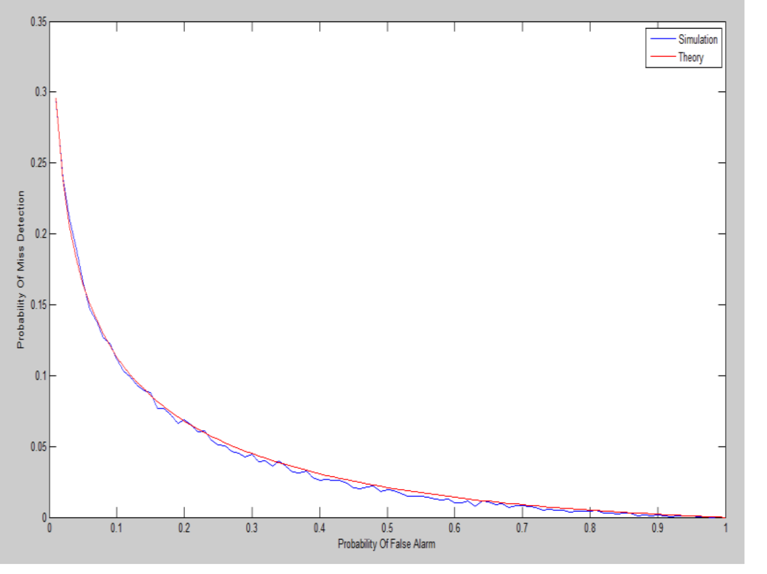
Description:- In the following program, ROC curve between probability of false alarm vs probability of miss detection is generated as it is helpful for analyzing failure of the device.

Program –

```
clc
close all
clear all
GraphicalPoint = 1000;

snr_in_dB = -10;
snr = 10.^(snr_in_dB./10);


%-----Probability of False Alarm-----%
Pf_A = 0.01:0.01:1;

%% Simulation to plot Probability of
Detection (Pd) vs. Probability of
False Alarm (Pf_A) %
```

```
for m = 1:length(Pf_A)
    Detect = 0;
    for num_MonteCarlo_sim=1:10000 %
Number of Monte Carlo Simulations

        %-----AWGN noise with mean 0
and variance 1-----%
        Noise =
randn(1,GraphicalPoint);
        %-----Real valued Gaussian
Primary User Signal------%
        Signal =
sqrt(snr).*randn(1,GraphicalPoint);
        Recv_Sig = Signal + Noise; %
Received signal at SU
        Energy = abs(Recv_Sig).^2; %
Energy of received signal over N
samples

        %-----Computation of Test
statistic for energy detection-----%
        Test_Statistic
=(1/GraphicalPoint).*sum(Energy);

        %-----Theoretical value of
Threshold-----%
        Threshold(m) =
(qfuncinv(Pf_A(m))./sqrt(GraphicalPoin
t))+ 1;

        if(Test_Statistic >=
Threshold(m))  % Check whether the
received energy is greater than
threshold, if so,(Probability of
detection) counter by 1
           Detect = Detect+1;
        end
end
Pd(m) = Detect/num_MonteCarlo_sim;
Pm(m) =1-Pd(m);
end

plot(Pf_A, Pm)
hold on
%% Theroretical expression for
Probability of Detection
Threshold =
(qfuncinv(Pf_A)./sqrt(GraphicalPoint))
+ 1;
Pd_the = qfunc(((Threshold - (snr +
1)).*sqrt(GraphicalPoint))./(sqrt(2).*
(snr + 1)));
Pm_the = 1- Pd_the;
plot(Pf_A, Pm_the, 'r')
xlabel('Probability Of False Alarm');
ylabel('Probability Of Miss
Detection');
legend('Simulation','Theory');

hold on
```

Simulation Result:-



Program 3:-

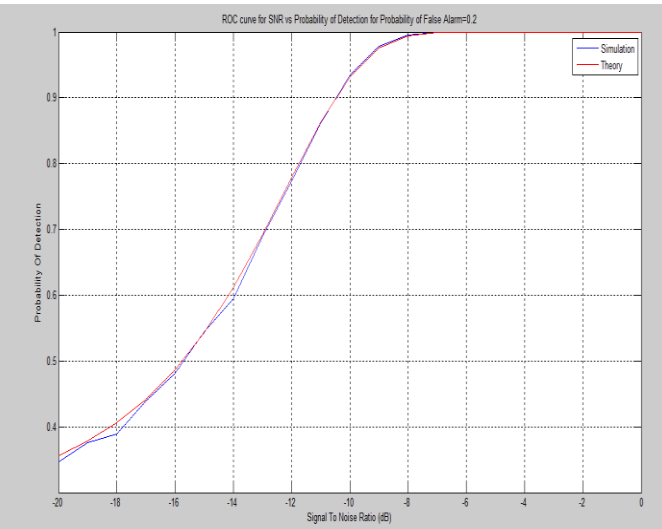
Description:-In the following program, ROC curve between SNR versus Probability of detection at probability of false alarm=0.2 is generated and is seen that SNR is high.

Program –

```
%%

clc
close all
clear all
GraphicalPoint = 1000;

snr_in_dB=-20:1:0;
snr= 10.^(snr_in_dB./10);

for i=1:length(snr_in_dB)
    Detect=0;
    Pf=0.2;
     for num_MonteCarlo_sim=1:10000 %
Number of Monte Carlo Simulations

        %-----AWGN noise with mean 0
and variance 1-----%
        Noise =
randn(1,GraphicalPoint);
        %-----Real valued Gaussian
Primary User Signal------%
        Signal =
sqrt(snr(i)).*randn(1,GraphicalPoint);
        Recv_Sig = Signal + Noise; %
Received signal at SU
        Energy = abs(Recv_Sig).^2; %
Energy of received signal over N
samples

        %-----Computation of Test
statistic for energy detection-----%
```

```
        Test_Statistic
=(1/GraphicalPoint).*sum(Energy);

        %-----Theoretical value of
Threshold-----%
        Threshold =
(qfuncinv(Pf)./sqrt(GraphicalPoint))+
1;

        if(Test_Statistic >=
Threshold)  % Check whether the
received energy is greater than
threshold, if so,(Probability of
detection) counter by 1
           Detect = Detect+1;
        end
end
        Pd(i) =
Detect/num_MonteCarlo_sim;
        Pm(i)=1-Pd(i)
        Pd_the(i) = qfunc(((Threshold
- (snr(i) +
1)).*sqrt(GraphicalPoint))./(sqrt(2).*
(snr(i) + 1)));
        Pm_the(i)=1-Pd_the(i)
end
 plot(snr_in_dB,Pd);
 hold on
 plot(snr_in_dB,Pd_the,'r');
 grid on
 title('ROC curve for SNR vs
Probability of Detection for
Probability of False Alarm=0.2')
 xlabel('Signal To Noise Ratio (dB)');
 ylabel('Probability Of Detection');
 legend('Simulation','Theory');
```

Simulation Result:-



Program 4:-

Description:- In the following program, ROC curve between Threshold and Total error rate of total 10 CR relays is modelled in a network and we have seen that at 5 Error rate is minimum.

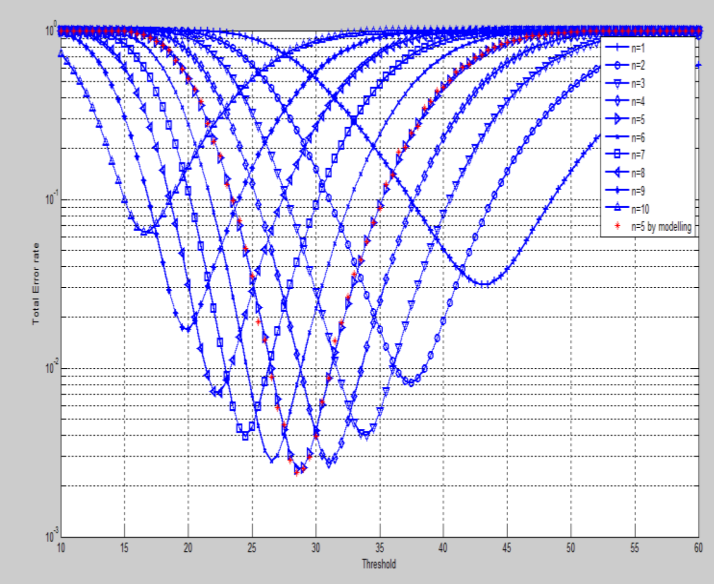
Program –

```
%%Spectrum Sensing Network
Optimization in CR with energy
detection to minimise total error rate
%
%

clc;
close all;
clear all;
N=20;
j=1;
range=[];
err2=[];
Pmi=[];
Pdc=[];
error=[];
err1=[];
K=10;
snr=10;
Qd=0;
Qf=0;
range=10:0.5:60;
symbolVector=['-+','-o','-v','-d','-
>','-x','-s','-<','-*','-^'];

for n=1:1:10

s=ones(1,N);
w=randn(1,N);

u=N/2;                     %Time-delay
bandwidth product

for t=10:0.5:60

Qd=0;
Qf=0;
SNR=10^(snr/10);   %for linear scale

a=sqrt(2*SNR);
b=sqrt(t);

Pd = marcumq(a,b,u );
% AVERAGE PROBABILITY OF DETECTION

Pf = gammainc((t/2),u,'upper');% AVG.
PROB OF FALSE ALARM

Pm=1-Pd;                      %AVG. PROB OF
MISSED DETECTION OVER AWGN
for l=n:1:K
Qd=Qd+(factorial(K)*(Pd^l)*((1-Pd)^(K-
l))/(factorial(l)*factorial(K-l)));
Qf=Qf+(factorial(K)*(Pf^l)*((1-Pf)^(K-
l))/(factorial(l)*factorial(K-l)));
end
```



```
Qm=1-Qd;
err=Qf+Qm;
err1=[err1 err];
end

end
l=1;
i=1;
for j=1:1:10
semilogy(range,err1(i:i+100),symbolVec
tor(l:l+1),'LineWidth',1.5)
i=i+101;
l=l+2;
hold on;
end
grid on;
ylabel('Total Error rate');
xlabel('Threshold');


%----------------------Energy
Detection------------------------------
-----------
n=5;
rel=10000;
range1=10:0.5:60;
er1=[];
for t=10:0.5:60
Pdc=0;
Pfc=0;
Qd=0;
Qf=0;
Qm=0;

for i=1:1:rel
SNR=10;

snr=10^(SNR/10);


s=ones(1,N);
w=randn(1,N);
vari=var(w);                    %variance
of noise

Es=sum(s.^2);

N02=(Es)/(2*snr);

x1=s+w;
x2=w;
W=1;                         %Time-delay
bandwidth product

E0=(sum(x2.^2))/((W*N02));

E1=(sum(x1.^2))/((W*N02));


if E1>t
    Pdc=Pdc+1;
else
end
if E0>t
    Pfc=Pfc+1;
else
end
end
Pd=Pdc/rel;
Pf=Pfc/rel;


for l=n:1:K
Qd=Qd+(factorial(K)*(Pd^l)*((1-Pd)^(K-
l))/(factorial(l)*factorial(K-l)));
Qf=Qf+(factorial(K)*(Pf^l)*((1-Pf)^(K-
l))/(factorial(l)*factorial(K-l)));
end
Qm=1-Qd;
er=Qf+Qm;
er1=[er1 er];
end
hold on;
semilogy(range1,er1,'*r')
grid on;

ylabel('Total Error rate');
xlabel('Threshold');
legend('n=1','n=2','n=3','n=4','n=5','
n=6','n=7','n=8','n=9','n=10','n=5 by
modelling');
```

Simulation Result:-



6. Conclusion: -

In this work channel state estimation is proposed by energy detection (as opposed to feature detection—requires prior knowledge of the PU's Signal) and transmission or reception is carried out in a multiple spectrum hole for lower probability of communication loss.

7. Expected result :-

- Better power spectrum density versus frequency response for lower SNR also.
- Low probability of false alarm versus SNR.

8. Application:-

- Leased Network
- Emergency Network
- Military Network
- CR Mesh Network
- Multimedia
- Cellular Network

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