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Medium Access Probability of Cognitive Radio Network Under ECC-33/Hata-Okumura Extended Model Using Different Fading Channels at 1900MHz and 2100MHz

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ABSTRACT

Cognitive radio detects the presence or absence of Primary User (PU) in its sensing region to provide the free radio spectrum to its Secondary user (SU). It is widely accepted a SU is only allowed to access a network of PU when no PU of that network is accessing the network at that moment. Sometimes SU misjudges the presence of PU inside the sensing region though the PU is in transmitting mode outside the sensing region which is termed as spatial false alarm. The incorporation of spatial false alarm makes the task more difficult. Previous literature performs this task using Lee's path loss model .In our paper we have considered ECC-33/ Hata-Okumura Extended Model for two frequencies 1900MHz and 2100MHz as its frequency range is up to 3.5 GHz and compare the performance using different fading channels such as Rayleigh, Nakagami-m, Normal or Gaussian, Weibull, MRC Rayleigh and Selection Combining Rayleigh.

Keywords: *path loss model;fadingchannel;medium access probability;spectrum sensing; spatial false alarm.;conventional false alarm ,PMA*

I. INTRODUCTION

Due to the today's insufficient utilization of the radio spectrum, cognitive radio system has become major tool for the solution of the underutilized radio spectrum.Radio spectrum is getting very limited for the popularity of wireless devices. Limitations of the frequency spectrum cannot maintain the high requirement of spectrum usage. FCC (Federal Communications Commission) has found that in a particular location and at particular time the radio spectrum is fully occupied by its licensed user but in some location and at some time it is heavily underutilized [1]. The main function of Cognitive Radio is divided into four parts: spectrum sensing, spectrum management, spectrum mobility and spectrum sharing [2]. Cognitive radio allows SU to operate in the radio spectrum band without hampering PU .When transmitting a signal between transmitter and receiver attenuation or dispersion or distortion of the signal can happen for several reasons. In spatial false alarm (SFA) problem, a busy PU outside the sensing range can be detected by SU. Therefore, the SU misinterprets that the PU is inside its sensing range, and SU can't use the primary channel. Spatial False Alarm (SFA) decreases SU's medium access probability. A method was proposed [3] to solve this problem that is effective to improve negative impact. In Medium access probability, SU senses no busy PU is inside the sensing region. For finding the expression for medium access probability in cognitive radio and the effect of SFA a theory has been proposed [3]. To obtain the probability of correct decision in received signal using Normal distribution of fading channel was used in [4].The work was enhanced in [5] by using three small scale fading channels Rayleigh, Rician and Nakagami-*m* to obtain the scenario in urban area. This work is again enlarged in [6] by using different fading channels under two path loss models (Lee's and Okumura-Hata path loss model) in urban area. The work has further increased [8] by using Lee's path loss model using six fading channels such as Rayleigh, Normal, Nakagami-*m*, Weibull, MRC Rayleigh and Selection Combining Rayleigh.

Demand for huge bandwidth paves the way for 4G technology.4G offers what consumers want. This technology provides many advances to the wireless market, including downlink data rates over 100 megabits per second (Mbps), low latency, very efficient spectrum use and low cost implementations.4G technology has two standards that are widely used: WiMAX and Long Term Evaluation (LTE). In this paper we enhance the previous work [8] by using ECC-33/ Hata-Okumura Extended Model under different fading channels such as Rayleigh, Normal, Nakagami-*m*, Weibull, MRC Rayleigh and Selection Combining Rayleigh for frequency 1900MHz and 2100MHz as these frequencies are compatible for 4G communication.

The paper is organized as follows: Section II describes the system model of the work, where ECC-33/Hata-Okumura Extended model is described, sensing requirement in CRN and medium access probability& SFA problem is also described. In Section III we describes the result of the investigation in details and finally Sec. IV. Conclusion is given.

II. SYSTEM MODEL

A. ECC-33/Hata-Okumura Extended Model

Hata-Okumura extended model or ECC-33 Model is one of the most widely used empirical propagation models [9], which is founded on the Okumura model. Okumura model doesn't provide any data greater than 3 GHz. International Telecommunication Union (ITU) expanded this model for further extension up to 3.5 GHz. This model is largely used in urban environments particularly in large and medium size cities [10]. This model is developed by Electronic Communication Committee. The path loss model is defined as [11],

$$PL = A_{fs} + A_{bm} - G_b - G_r \qquad (1)$$

Where;
A_{fs}: Free space attenuation
A_{bm}: Basic median path loss
G_b: Transmitter antenna height gain factor
G_r: Receiver antenna height gain factor.

They are individually defined as:

$$A_{fs} = 92.4 + 20log_{10}(d) + 20log_{10}(f) \qquad (2)$$

$$A_{bm} = 20.41 + 9.83log_{10}(d) + 7.894log_{10}(f) + 9.56[log_{10}(f)]^2 (3)$$

$$G_b = log_{10}\left(\frac{h_b}{200}\right)\{13.958+\}5.8[log_{10}(d)]^2 \qquad (4)$$

For medium cities, G_r will be expressed in:

$$G_r = [42.57 + 13.7log_{10}(f)][log_{10}(h_r) - 0.585] (5)$$

For large cities,

$$G_r = 0.759h_r - 1.862 \ (6)$$

B. Sensing Requirement in CRN

Let us consider a cognitive radio network with N number of sample channels where SUs are allowed to opportunistically access the network without hampering the QoS of the PU. In this case the SU's sensing region (r_s) plays an important role in ensuring the primary receiver and secondary receiver are not interfered by each other [12].For a specific r_s, the signal-to-noise (SNR) in secondary user's detector can be expresses as [4]:

$$\gamma = \frac{S_r}{{\sigma_n}^2} = S_t h(r_s)/{\sigma_n}^2 \qquad (7)$$

Where $S_r$is the PU's transmit power received at SU's detector, S_t is the PU's transmit power, ${\sigma_n}^2$ is the noise power and $h(.)$ is the channel gain. The sensing objective is to detect the real on-off state of the PU inside the sensing region of SU. In this case one of the two hypotheses H_0 (denotes PU is off) and H_1 (denotes PU is on) is used by analyzing the received signal *x[n]* [13]-[16]:

$$H_0: x[n] = w[n], \ n = 0,1,2, \ldots\ldots, N-1 (8)$$

$$H_1: x[n] = he^{j\varphi} S_r[n] + w_n, \quad n = 0,1,2, \ldots.., N-1 \qquad (9)$$

Where *w[n]* is the noise signal in the channel. It will considered to be complex Gaussian random variable with zero-mean and variance ${\sigma_n}^2$;$S_r[n]$ is the n^{th} sample of the PU
signal received at SU detector and N is the total number of sample.

C. Medium Access Probabilit and SFA Problem

Medium access probability is the probability of detecting the presence/absence of PU inside the sensing region of SU correctly. As widely known, a SU can access the primary channel when the PU is not in transmitting mode inside the sensing region or transmitting mode but outside the sensing region of SU. Traditionally false alarm happens when a SU treats a PU in "busy mode" inside the sensing region whereas the PU is only "on" state or not being present inside the sensing region. Again misdetection happens when a SU detects no PU inside its sensing region but the PU is actually in transmitting mode inside the sensing region. In reality we face another type of error, although the distance between the PU and the SU is longer thanr_s, the SU can still sense the presence of PU with a certain detection probability. This is because the detection probability does not decrease efficiently as the distance between PU and SU increases. Since the SU can still sense the presence of busy PU outside the sensing region, it can misjudge this presence as inside the sensing region and hence loses the opportunity to access the channel. This problem is termed as spatial false alarm problem [SFA], which is similar to traditional false alarm problem in detection theory.

Therefore, state H_o can be further categorized into two subsets as [5]:

$$H_0 = \begin{cases} x[n] = w[n] \quad n = 0,1,2, \ldots, N \\ x[n] = he^{j\varphi} S_{r,+}[n] + w_{n}, n = 0,1,2, \ldots.., N-1 \end{cases} (10)$$

Where, $S_{r,+}$ is the PU's transmit power received by the SU when PU is just outside the sensing region.

Similarly, the hypothesis H_1 can be rewrite as[5]:
$H_1 : x[n] = he^{j\varphi} S_{r,-}[n] + w_{n\,,} \quad n = 0,1,2,\ldots.,N-1$(11)
Where $S_{r,-}$ is the SU's received power of PU inside its sensing region.

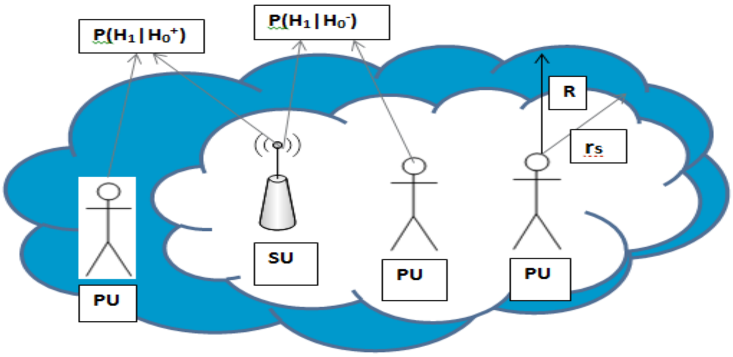

Figure 1.SUsensing reason &cell coverage area.

Therefore, to derive the probability of correct detection let us introduce the following probabilities:
$P(H_0^-|H_1)$: Probability of misdetection
$P(H_1|H_0^-)$: Probability of conventional false alarm
$P(H_1|H_0^+)$: Probability of spatial false alarm
$P(H_1|H_1)$:Probability of correct detection.
Without the impact of sensing error, the medium access probability $P_{MA}=P(H_0)=1-P(H_1)$ and is given by [4]:

$$P_{MA} = 1 - p\frac{{r_s}^2}{R^2} \qquad (12)$$

Where p is the probability of PU in transmitting mode inside the sensing region.
We will also consider the medium access probability with the impact of sensing error. We will now consider the case when PU is only "on" state inside the sensing region. Therefore, the probability of conventional false alarm will be found in [14] as:

$$P(H_1|H_0^-) = Q\left(\frac{\epsilon-\mu_0}{\sigma_0}\right) \qquad (13)$$

Where$Q(.)$ is the Q-function and ϵ is the detection threshold.
Therefore, the probability of correct decision will be:

$$P_{H1} = P(H_0^-)(1 - P(H_1|H_0^-))$$
$$= (1-p)\{1 - Q\left(\frac{\epsilon-\mu_0}{\sigma_0}\right)\} \qquad (14)$$

Again, let us consider the case when a PU is in transmitting mode but outside the sensing region. In that case, the probability of spatial false alarm will be

$$P(H_1|H_0^+)) = Q\left(\frac{\epsilon-\mu_1}{\sigma_1}\right) \qquad (15)$$

For a certain PU, the detection probability will be [2]:

$$p_d = Q\left(\frac{\epsilon-\mu_1}{\sigma_1}\right) \qquad (16)$$

As $\mu_1$and σ_1 are both related to distance between PU and SU $P_d(r)$ is a function of r when the value of S_t and N is given.
Since $P(H_1|H_0^+)$ is the probability of detecting the PU under the condition $R>r_s$, we can write:

$$P_{H2} = P(H_0^+)\{1 - P(H_1|H_0^+)\}$$
$$= p\left(1 - \frac{{r_s}^2}{R^2}\right) - p\int_{r_s}^{R} p_d(r) f_r\, dr$$
$$= P(1 - \frac{r_s^2}{R^2} - 2/R^2 \int_{r_s}^{R} Pd(r) r dr)$$
$$= P/R^2(R^2 - r_s^2 - 2\int_{r_s}^{R} Pd(r) r dr)(17)$$

Where $f(r)$ is the PDF of PU's location which can be given as:

$$f(r) = 2r/R^2 \qquad (18)$$

Therefore, the total medium access probability can be found as:

$$P_{MA} = P_{H1} + P_{H0} = (1-P)(1-Q((\in -\mu_0)/\sigma_0)) + P/R^2(R^2 - r_s^2 - 2\int_{r_s}^{R} Pd(r)rdr)$$

$$= (1-P)\left(1-P_f\right)) + P/R^2(R^2 - r_s^2 - 2\int_{r_s}^{R} Pd(r)rdr) \ (19)$$

Where $P_f = (Q((\in -\mu_0)/\sigma_0)$ (20)

In case of Rayleigh fading channel detection probability *Pd(r)* can be written as:

$$P_d(r) = \int_{\lambda}^{\infty} \frac{1}{\gamma_{av}} e^{-\frac{\gamma}{\gamma_{av}}} d\gamma \ (21)$$

III. RESULT AND DISCUSSION

In this paper, we have considered ECC-33 /Hata- Okumura Extended path loss model to evaluate the average SNR (Signal-to-Noise Ratio) at the receiver i.eγav is a function of large scale path loss parameters. At first the profile of medium access probability (PMA) against the probability of the access opportunity *P(H*0*)* for Nakagami-*m*, Rayleigh, Normal ,Weibull ,MRC Rayleigh and Selection combining Rayleigh fading environment have been observed. Two carrier frequencies: 1900MHz and 2100MHz used for 4G mobile communication are considered in this paper .In ECC-33 model we have considered the typical parameters as: *f*=1900 MHz and 2100MHz,*r*=1000km,*hR*=6m,*hB*=40m. For the case of Rayleigh fading channel, the only parameter is γav = 0.2 is a function of path loss parameter. For the case of the normal distribution σ = 0.42 and mean signal strength μ is function of path loss parameters. For the case of weibull fading channel β= 0.43 and α= 0.22 is a function of path loss parameters. For Nakagami-*m* fading case m = 2 and γav is a function of path loss parameters. Both for MRC Rayleigh and Rayleigh with selection combining scheme γav = 0.2 and Nr = 2. The PMA is found larger at 1900MHz compared to 2100MHz for the corresponding fading cases.

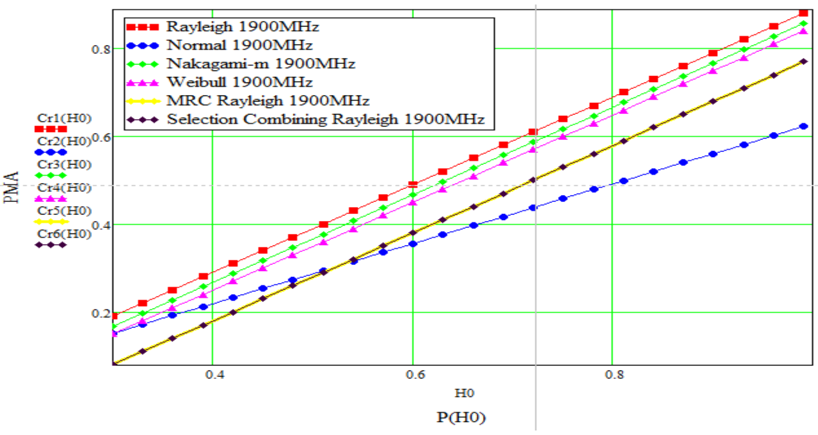

Figure 2.Performance comparison under ECC-33Model at 1900MHz.

If we particularly compare each fading channel with two frequencies then we have noticed that in 1900MHz the fading channels show better performance than the fading channels in 2100MHz. In case of ECC-33 /Hata-Okumura Extended model the receive signal is better condition for Rayleigh fading channel than other fading channels .So this fading channel will perform better for this path loss model. If we compare all the six fading channels at a particular carrier frequency, the PMA in descending order are: Rayleigh, Nakagami-*m*, Weibull, Selection Combining Rayleigh, MRC Rayleigh and Normal.

In [8], it is found that the received signal is in better condition for Weibull fading channel in Lee's path loss model. These signalsare not close to each other and risesexponentially. But in our work we have found that the received signal is in better condition for Rayleigh fading channel and the signals follow a linear relationship with *P(H*0*)*.

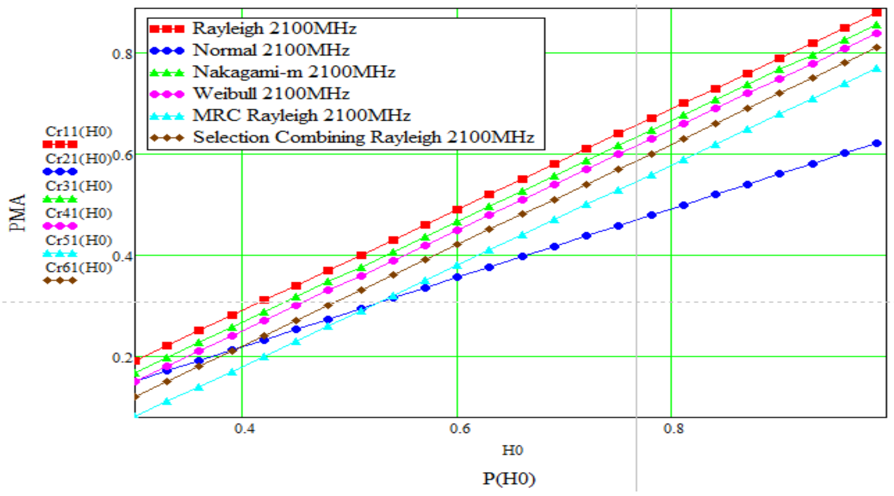

Figure3.Performance comparison under ECC-33 Model at 2100MHz

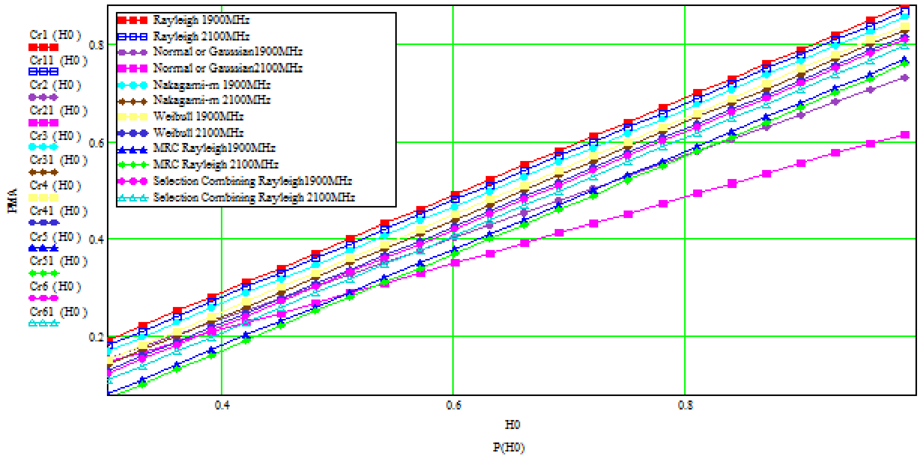

Figure4.Performance comparison under ECC-33 Model at 1900MHz and 2100MHz

IV. CONCLUSION

In this paper, the main focus is to enhance the usability of unused spectrum in radio frequency band. We have considered ECC-33 /Hata-Okumura Extended path loss model under different fading channels at frequency 1900MHz and 2100MHz and simulate the equations for this model.The performance of cognitive radio network based on medium access probability under Nakagami-*m*, Rayleigh, Normal, Weibull,MRC Rayleigh and Selection Combining Rayleigh fading environment have been evaluated. We have considered the frequencies of 1900 and 2100MHz as they are compatible for 4G mobile communication networks .This path loss model is suitable for urban environments particularly in large and medium size cities. The result of the simulation shows the performance of different fading channels for a specific model namedECC-33 /Hata-Okumura Extended model .It will be helpful for providing more accurate signal coverage of modern wireless network. The entire work can be extended incorporating other path loss models using different fading channels.

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