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Spatial Diversity Impact in Mobile Quantisation Mapping for Cognitive Radio Networks

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***Abstract*—Mobile environment especially spatial diversity in spectrum exchange information in cognitive radio networks is an interesting topic for further investigation. Most of the cognitive radio researchers does not consider the spatial diversity of sensing nodes. However, the mobility of the SNs within PU's coverage area is heavily influencing the detection performance on local observation of energy signals. The movement of the SNs creates spatial diversity in the observation of the PU's signal. Due to the movement, spatial distance, velocity, Doppler Effect and geo-location information, the signals condition would fluctuate during the sensing process. Spatial diversity also reduces the average received signal strength and must be compensated by detection signal method which appropriate with the signal conditions. Therefore, it is need to find a comprehensive solution to overcome the effects of spatial diversity. Moreover, this research could give a clearly analysis in spectrum exchange information regarding detection performance for cognitive radio networks. Finally, the cooperation overhead due to spatial diversity effects in master node station could reduce and increased the detection performance of PU's spectrum hole channels**

Keywords—Spatial Diversity, Spatial Spectrum Sensing, Quantization Mapping, Mobility Nodes, Cognitive Radio Networks

I. INTRODUCTION

Numerous investigations have been accounted on cooperative spectrum exchange concerning the stationary node in cognitive radio networks (CRN [1]–[3]. In many studies, effort to spectrum exchange information also known as quantization mapping or subcarrier mapping into some bit information has been considered. The aim's is to reduce the use of bandwidth that information exchange is reported or sharing to the master node (MN) or neighbor. In [4] has introduce the detection of the energy level is quantizing into some bit to combat degradation performance in multipath fading reporting channel. Similarly, two quantization methods were developed by [5] that could reduce bandwidth consumption by identifying the reporting SN to MN with binary decision (0, 1). Exchange information has also been considered in the study of local decision information. As reported by [6] that has developed space time block coding over several OFDM sub-channels for two CR users which can exchange their decision trough a predefined protocol. However, predefined protocol and relay diversity has increased the complexity of frequency-selective fading channels.

In [7] proposed the cooperative spectrum sensing using single orthogonal subcarrier that combat bandwidth limitation on reporting channel by quantized the detection power level into a tone signal of OFDM. Moreover, [8] proposed the cooperative networking without common control channel, this method aimed to reduce complexity function using M orthogonal sub-channel that equally divided from the licensed band.

As shown in [7], the effective method that could combat bandwidth limitation is quantized the observation power detection into OFDM tone signal using subcarrier parameter. Therefore, the reporting channel is reduced. The quantized power into subcarrier bit remains in overhead problems. However, the studies has shown that the SN's stations are assumed stationary. Whereas, spatial parameters have contributed the performance of wireless networks. The received signal power, distance, phase angle and velocity of the nodes are influences the performance of sensing nodes. Therefore, wireless users have facing the problem of traditional cellular networks such as an irregularly infrastructure, spatial configuration and un-planned antennas tilt positions which limitations to the capacity network access[9]. Therefore, a comprehensive analysis is needed so that it can contribute to the efficient use of the frequency spectrum in cognitive radio networks.

II. SPATIAL SPECTRUM SENSING FOR DYNAMIC SPECTRUM ACCESS (DSA)

In [8] has proposed spatial opportunity and coverage probability. Moreover, the average spatial density has successfully transmitted in the primary/secondary network, under the PRA and PTA protocols, respectively. While in [10] has been investigated of spatial interpolation techniques based on Inverse Distance Weighting (IDW) is analyzed. The spatial interpolation techniques can provide a robust and reliable Radio Interference Field (RIF) estimation within the entire REM concept. Furthermore, [11], [10] and [12] has deployed spatial statistic techniques which have a natural use in the analysis of Dynamic Spectrum Access (DSA) opportunities. They show that how locations of primary and secondary can be characterized using spatial statistic techniques. In future, using spatial statistic techniques has been proposed as foundation for new models of spectrum sharing algorithm and protocols.

Whereas, in [13] PU mobility are studied to determine the parameters that affect the spectrum sensing functionality. There are two performance metrics that influences the measurements of the PU mobility impact on the CR user detection probability and secondly is measure the presence of transmission capacity by CR users. However, PU mobility doesn't impact to CR users with note that the protection of PU range must be activated. Moreover, in [14] a joint spatial-temporal spectrum sensing scheme is proposed, which exploits information from spatial sensing to improve the performance of temporal sensing. The results show that the probability of spectrum hole detection and capacity gain has been perform significantly in single primary transmitter. In other hand, a novel spectrum opportunity has been exploited by [15] proposed a spatial spectrum hole (SH) to assist the communication by using other spatial domains. The successful communication probabilities of CR users were deployed has been performed. However, the number of relay hops increases, more complicated protocols are involved, which decreases the CR's throughput.

Exploiting spatial diversity based on its energy power has improve the mobility of sensing performance has stated in [16]. They studied the mobility driven of CR node within available bandwidth that moving with a certain speed that correlated in decision of PU signal. The mobility speed of CR node is correlated to shadowing that use exponential model that defines the function of mobile nodes. In [17] has exploiting cross layer platform to investigate the mobility-aware sensing node which consider some parameters such as power, reliability, traffic, delay, autonomy and coexistence.

The cooperative spectrum sensing requires bandwidth resources efficiently. It should be intelligently identifying communication types and able to sense availability of sensing dimensions cognitively. To addressing the limitation channel resource, sensing nodes requires information exchange among them in a group of cognitive networks. By convert the spectrum energy into subcarrier number of OFDM signals known as subcarrier quantization mapping. In this exchange procedure, most of the researchers assuming that mobility parameter without considering spatial diversity effect. The spatial diversity are causes the sensing node need some proper quantization techniques to adapt the spatial effect. The effect of the spatial diversity has raise the probability of the spectrum hole that might be shifted or losses its time and space as a results from the interaction with transmission channel. Therefore, exchange procedure has raises some overhead process that are burdened into communication link thus the cost become expensive due to the timing offset, synchronization, interference and bandwidth. Furthermore, the nodes should use very high sensitivity receiver that can measure the present signal in the surrounding.

III. SPATIAL SPECTRUM SENSING MODEL FOR SPECTRUM EXCHANGE INFORMATION IN COGNITIVE RADIO NETWORKS

This method is proposed to investigate the spatial diversity parameter, subcarrier quantization mapping in mobility nodes and spectrum mobility effect in spectrum exchange information. Fig. 1 shows the performance of mobility effect model in sensing node.

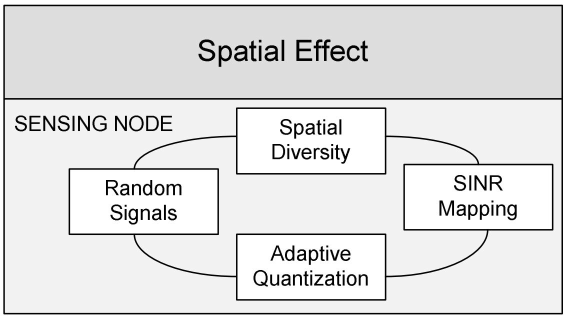


Fig. 1. Spatial diversity effect scenario for individual sensing node

The method is presented spatial model for individual sensing node to perform spectrum exchange information. Path loss signal power attenuation with the distance form primary user is used. Well known path loss model such Friis and Nakagami model is utilized under simulation setup. The model expresses the path loss as a function of spatial parameters of every single SN's node, signal to interference noise ratio and the type of environment. The spatial diversity causes nodes need a proper quantization technique to adapt the spatial effect. The effect of the spatial has raise the probability of the spectrum hole that might be shifted its time and space as a results from the interaction with transmission channel.

Therefore, SINR wall for mapping is a change refers to the influencing of spatial diversity. This could be challenge for subcarrier quantisation mapping of an individual sensing node. In this works, maximum points for each SN that receives the signal base on the distance randomly and its effects are investigate, if SN's is in the boundary area, then SN within the scope of MN. Now if there are moveable nodes, here we have to choose a method that can show a good performance in spectrum exchange information for cognitive radio networks. When SN's moving and start sense the surrounds instantly, there is interference of power from surrounding environment.

TABLE I. SIMULATION PARAMETERS [18]:

Master Node:	Frequency Requested = 100e2;
	SNR master node = 30; dB
	Number of Sensing Node = 10
Subcarrier detection threshold at master node	11.5 ; dB
Channel Model	AWGN, Rayleigh fading
Subcarrier mapping parameter	5
Range of subcarrier mapping	-infinite ~20.1 [dB]
Pre-determine false alarm probability	0.1
Received power (*Xi*) level of SN's	[-100 dB – (RSSI)]
Number of samples per nodes	128
Frequency	2.4 GHz
Radius of primary service area	1000 m

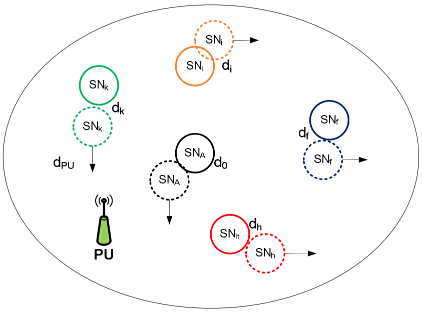


Fig. 2. Multiple sensing nodes (solid dots with arrow) can opportunistically use the licensed channels of PU only when the distance from any active PU's is greater than a certain threshold γ_m.

Based on Fig. 2 and Fig. 3, we derived that the nodes have a distance difference could be representing as follows [19]:

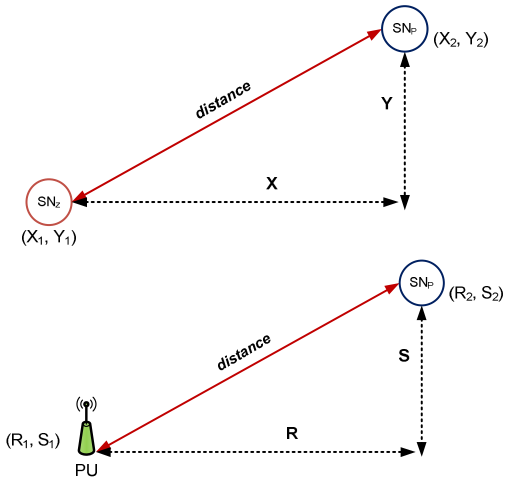


Fig. 3. Measurement of spatial distance difference each sensing nodes and PU's Station

$$d_{distance}(i) = \sqrt{x^2 + y^2} \tag{1}$$

Where $x = x_2 - x_1$ and $y = y_2 - y_1$
Thus, the distance difference model is given by

$$d_{PU} = \sqrt{(r_2 - r_1)^2 - (s_2 - s_1)^2} \tag{2}$$

$$d_{SN} = \sqrt{(x_2 - x_1)^2 - (y_2 - y_1)^2} \tag{3}$$

In this work, we proposed the utilization of aggregate-interference as the input of inter subcarrier k-calculation among collocated sensing node users. Whenever SN's start moving, the velocity is given by

$$v_r(i) = \left(\frac{\Delta d_{SN}}{\Delta t_{SN}}\right)\cos\theta \tag{4}$$

$V_r(i)$is velocity speed of SN's in meter per seconds (m/s) and Δt is time travel which is needed to moving from source place to current position, d'_{SN} in second, and $\cos\theta$ is the angle of arrival (AoA) position.

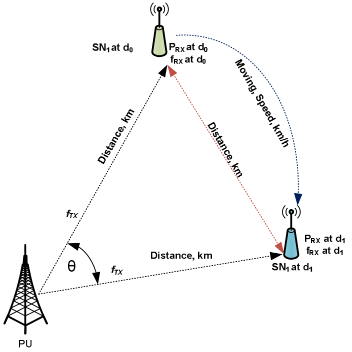


Fig. 4. SN's power detection corresponding to the distance travelled and angle of arrival (AoA)

When the SN's is moving in certain speed, causes a shift frequency of the signal transmitted through the length of signals path. The different path of the movement impact to the differ angle of arrival of the SN position therefore the received frequency can be different. This condition known as Doppler frequency shifted also known as angle of arrival (AoA).

In this case, whenever the SN is moving forward towards closer to the PU, according to the trigonometric law, the distance that measured is the hypotenuse of a right angle triangle with angle θ so it has side's $sin^{-1}\theta$. To estimate Doppler frequency shifted *theta* or AoA of the SN's is consider measured. As illustrated in Fig. 4, the distinction of the frequency received (AoA) each movement of SN's node is given by

$$\theta\ (i) = arccos\left(\frac{\left(d_{x-SN}(i) - d_{x-PU}(i)\right)}{\Delta d_{SN}(i)}\right) \tag{5}$$

As illustrated in Fig. 4, suppose that the frequency and power of the transmitted signal is f_T and P_T, respectively; the detected signal with a frequency f_R and the Doppler shift is given by

$$f_R(i) = f_T\left(1 + \frac{2V_r\cos\theta}{c}\right) \tag{6}$$

where V_r is the velocity of the SN, $\cos\theta$ is the SN's target angle, c is the speed of light, f_T is the frequency transmission (carrier frequency).

The distance of primary transmitter to sensing nodes is considering path loss factor. Moreover, the distance from the primary transmitter to the individual sensing can be obtained by [20]

$$\mathrm{L_{pu}} = 20\log_{10}\left\{\frac{\lambda}{4\pi \mathrm{d_0}}\right\} - 10\mathrm{n}\log_{10}\left\{\frac{\mathrm{d_0}}{\mathrm{d_{PU}}}\right\} \tag{7}$$

The received signal power P_{PU} in the i^{th} SN's is denoted by $P_{R(SN)}(i)$, where is known as SINR$_{\text{-wall}}$ is given by:

$$\begin{aligned} &SINR_{Wall(at\,SN_N)} \\ &= P_{PU}(power) \\ &- 20log_{10}\left\{\frac{(4\pi^2 * ((d_0(i) - d_{PU}(i)) * 2)}{\lambda}\right\} \\ &+ \sum_{i=1}^{I}\Bigg(P_T(SN_i)(i) \\ &- 20log_{10}\left\{\frac{(4\pi^2 * ((d_0(i) - d_{SN}(i)) * 2)}{\lambda}\right\}\Bigg) + r(t)(i) \end{aligned} \tag{8}$$

Where $\mathrm{P_{PU}}$ is the received signal power that will normalize the received power of $\mathrm{P_{R(SN)}(i)}$; λ is the wavelength, $\mathrm{d_0}$ is reference distance, d_{PU} is the radius of the cooperative sensing area depending on the allowable transmit power of the sensing node; $\mathrm{d_{SN}}$ is the radius between sensing nodes; Where the $r(t)$ is Rayleigh fading based on summing sinusoids with Jakes model [21].

$$r_I(t) = \frac{1}{\sqrt{N}}\sum_{m=1}^{N}\cos(2\pi f_d cos\alpha_m t + a_m) \tag{9}$$

And

$$r_Q(t) = \frac{1}{\sqrt{N}}\sum_{m=1}^{N}\sin(2\pi f_d cos\alpha_m t + b_m) \tag{10}$$

$$r(t) = r_I(t) + jr_Q(t) \tag{11}$$

f_d is the Doppler shift, $a_m = b_m$ is the amplitude of the signal and N is multipath components with angle of arrival α_m of the nodes.

Every mobile SN's nodes will receives some distributed power from primary users (PU), and quantized into subcarrier mapping which is given by

$$k'_{Spatial} = \left[1 \pm \frac{\Delta f_R}{f_i}\right] * k_{Old} \tag{12}$$

Therefore, spectrum exchange information processing has been converting in $K_{Spatial}$ subcarrier mapping symbols. Where f_i is distinction in varies is subcarrier width, hence

$$\text{if } f_i \gg \Delta f_R \text{ then } k' = k \quad (13)$$

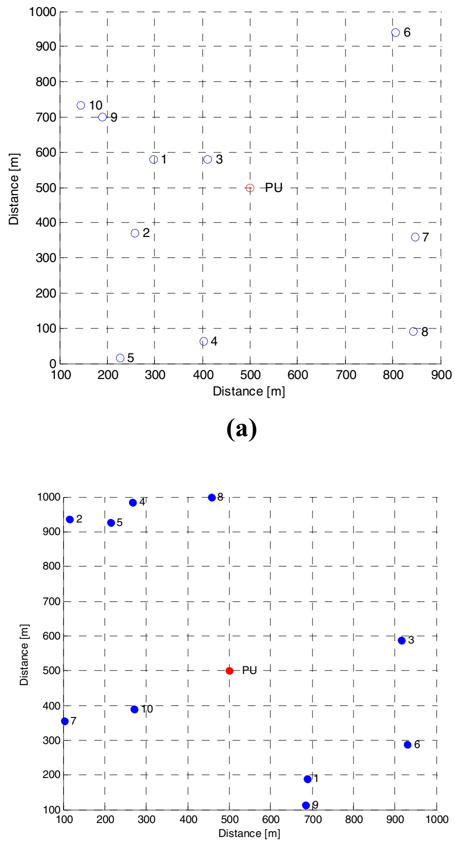
where f_R the maximum received frequency Doppler shifted at the nth sensing nodes [22]. The conventional quantization mapping (k_{Old}) of the spectrum exchange information at i^{th} SN's given by [20]

$$k_{Old}(i) = \left\lfloor P_{R-SN}(i) * \frac{N_c}{\alpha} \right\rfloor \quad (14)$$

where P_{R-SN} is received signal power of primary transmitter, N_c is number of subcarrier OFDM signal and α is subcarrier width parameter.

IV. RESULTS AND ANALYSIS

Fig. 5, (a) and (b) shows the location of the individual sensing node that mobile within PU area. In this case, the sensing node located within boundary areas mobile randomly. In that situation, individual nodes check their own situation within certain time sensing to observe the primary signal. Each node converts the sensing results to the subcarrier OFDM. All individual nodes simultaneously transmit the narrow band signal at the converted subcarrier OFDM to the master node by using pre-determined power transmit, 30 dB. In this works, the primary system is an OFDM system with 512 subcarriers at 2.4 GHz band. The required SIR power at the primary is 20 dB.



(a)

(b)

Fig. 5. (a) and (b) Two dimensional random spatial distance difference between PU-to-sensing nodes and SN-to-SN with ten nodes.

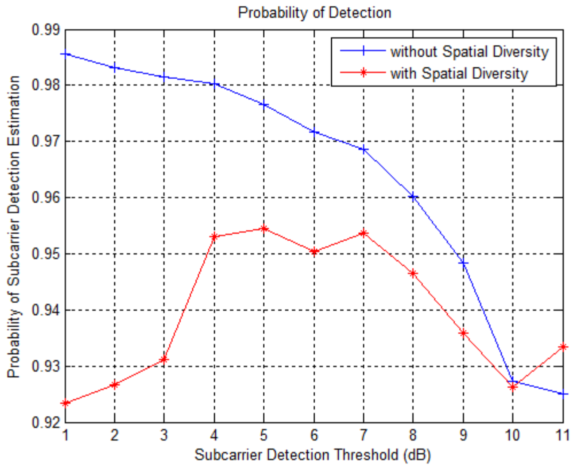


Fig. 6. The detection probability utilizing with and without spatial diversity and mobility parameters.

Fig. 6, show probability detection using spatial diversity, it shows that by varying movement of sensing nodes around primary transmitter, it has been proven that the spatial diversity parameters greatly affect the performance of a sensing node with the probability of detection of primary sources very fluctuating. On the range of subcarrier detection threshold from 4 dB to 8 dB, the detection probability is averaged. The adequacy of SN's to detecting power within the range of normative threshold values, so that detection can be done well. For that reason, we need a proper method that can overcome the weakness of detecting a primary signal by the sensing node when the sensing node moves at a variable speed. primary user transmitter based on the distance level.

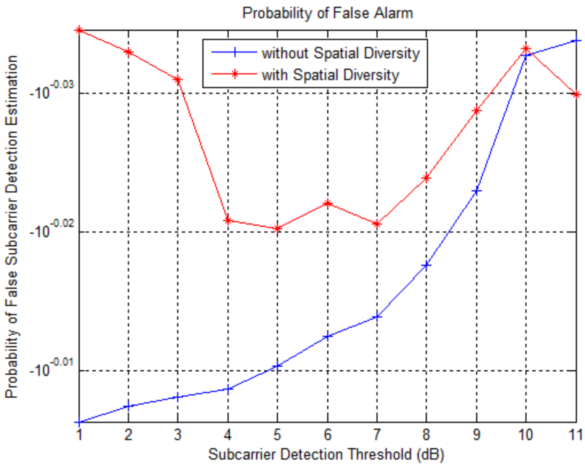


Fig. 7. Probability of False Alarm wit and without spatial diversity and mobility parameters

Fig. 7, show false alarm probabilities has fluctuating, since spatial diversity is deployed in sensing nodes. Therefore, huge false alarm detection probabilities have occurred and getting poor performance whenever nodes is moving. The results have shown that spatial diversity is very influential on the performance of the sensing nodes, so it should not be assumed that nodes are stationary or move constantly in calculations in a wireless environment.

V. CONCLUSION

It can be shown that the performance of spatial diversity greatly affected to the performance of spectrum exchange information. In the future the researchers should not assume again for each sensing node to pretend to be move. It must be with spatial parameters that are completely with real conditions in the wireless world. Furthermore, a proper quantization spectrum exchange model which adaptable or intelligently to the power detection fluctuating should be deployed to overcome the limitations.

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