Ray-Based Propagation Simulations for Probability of Missed Detection in Cognitive Radio Scenario

Xin Zeng
Francesco Mani
Alain Sibille
LTCI, Telecom ParisTech, Paris, France
(e-mail: xin.zeng@telecom-paristech.fr)

I. INTRODUCTION

The ever expanding requirements of wireless resources to connect people and machines put more and more pressure on the radiofrequency spectrum. Considering its intrinsic limitation, the ”command and control” static frequency allocation scheme leads to a congestion of the spectrum itself. Cognitive radio is expected to be a solution to this problem by introducing an opportunistic use of the frequency bands that are not heavily occupied by licensed users [1]. One of the key points of this technique is the capability to reliably detect the actual use of spectrum by legitimate users, in order to avoid interference with cognitive ones [2].

In this work we present the generation of coverage maps in terms of probability of missed detection (PMD) for active user systems, e.g. GSM 900 and 1800 and UMTS. The analysis is carried out considering propagation dependent path-loss. This is evaluated using a deterministic ray-launching approach, that is able to provide accurate results in terms of scenario dependence at the cost of a significant computational complexity.

II. ENERGY DETECTION AND PMD

A basic energy detector is considered in order to indicate frequency occupancy within the bandwidth of consideration. Energy detecting is a non-coherent detection method, taking advantage of simplicity and not requiring a priori knowledge of primary user signal. The two hypotheses on which the energy detector is designed to make the decision are:

$$x(t) = \begin{cases} n(t) & H_0 \\ h\cdot s(t) + n(t) & H_1 \end{cases} \tag{1}$$

where $x(t)$ is the signal received by sensor, $n(t)$ is additive white Gaussian noise (AWGN), h is the channel impulse response in the time domain and $s(t)$ is the primary user transmitted signal. The hypothesis H_0 represents the absence of an active primary user within the sensor coverage zone in the targeted frequency band, while the hypothesis H_1 denotes the opposite case. According to [3] and averaging out the uncertainty due to noise using a large time-bandwidth product, the output of the detector before the decision, i.e received energy per sample, can be approximated as:

$$\overline{Y} = \begin{cases} 2 & H_0 \\ 2+\gamma & H_1 \end{cases} \tag{2}$$

where γ denotes the signal-to-noise ratio (SNR). Therefore, the decision can be resolved to a simple threshold method and the threshold itself can be defined as $\lambda = 2 + \gamma_{min}$, where γ_{min} is the minimum SNR required by receiver to have adequate energy for decoding. Then, PMD can be calculated by:

$$P_{md} = \int_{-\infty}^{\gamma_{min}} f_{\gamma}(\gamma) d\gamma \tag{3}$$

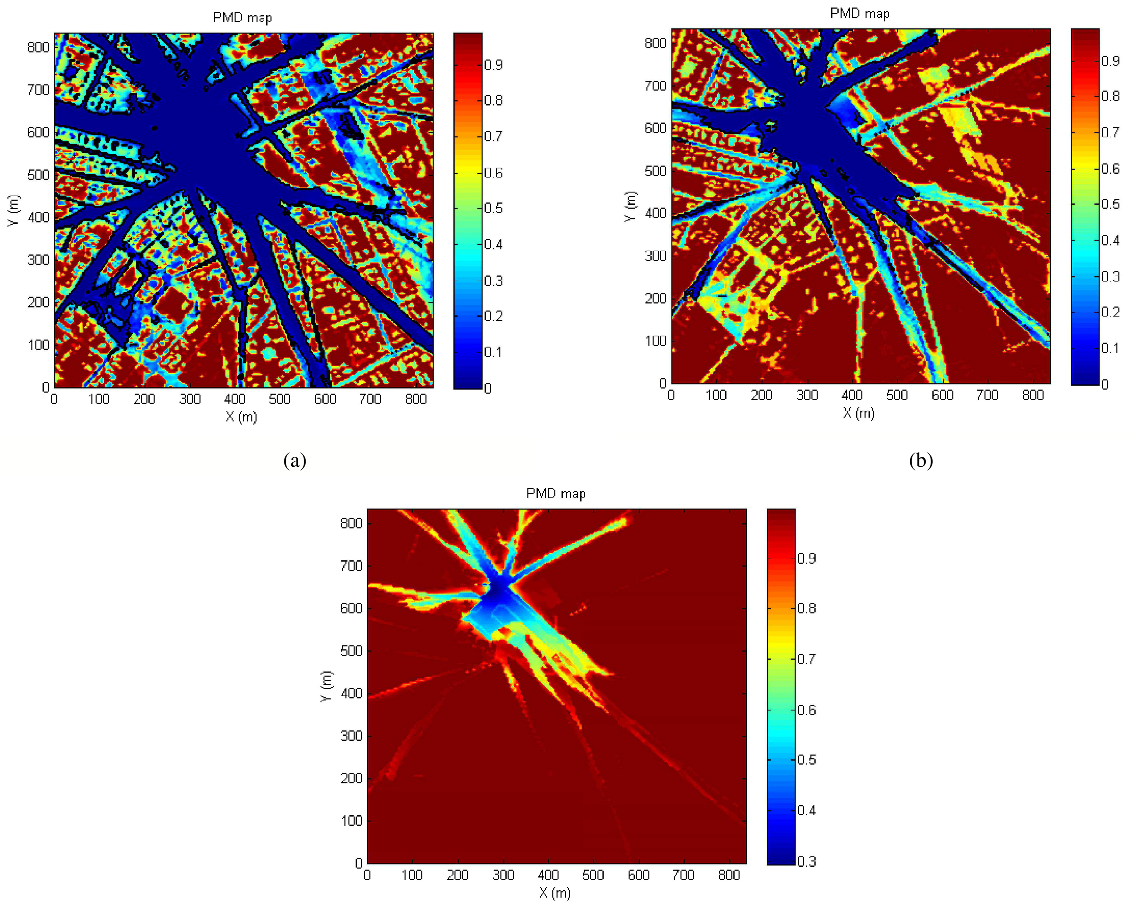
where $f_{\gamma}(\gamma)$ is the distribution of SNR.

III. GENERATION OF PMD MAPS WITH A RL MODEL

In this section, we present deterministic propagation simulations intended to estimate the PMD of a single sensor in a realistically described specific urban environment. The systems considered are GSM 900, GSM 1800 and UMTS with the carrier frequency of 900 MHz, 1800 MHz and 1950 MHz respectively. Four sensors are all settled on the masts 3 m higher than roof-top, detecting the radio wave emitted by MSs at 1.5 m above the ground level.

RL tool evaluates the path-loss that is substituted into Eq. 3 to deduce the PMD. Finally, the map of PMD is plotted to demonstrate the sensing coverage of the sensor.

Fig. 1 presents preliminary results in terms of PMD coverage map in single sensor mode, when considering only one of the sensor deployed. Due to high transmitted power in GSM systems, the coverage (in dark blue in the picture) stretches along the



(a)

(b)

(c)

Fig. 1. PMD maps for sensor 1 in case of (a) GSM 900, (b) GSM 1800 and (c) UMTS

main streets and some side-roads. Compared to GSM 1800, GSM 900 is operating at lower carrier frequency, which implies less path-loss by penetration and diffraction, leading to lower PMD even within buildings. Considering that the transmitted power is much lower in the case of UMTS compared to GSM, the PMD coverage is quite limitate, indicating the difficulty to detect such user. Since the processing gain allowing a low transmitted power cannot be obtained by a non-coherent detector, we suggest the sensor to include the demodulation function of UMTS, which can increase the SNR up to 25 dB. In that case, the coverage may approach the one of GSM systems.

IV. CONCLUSION

In this work, we firstly approximated PMD under the condition of large time-bandwidth product. Then, a ray-launching tool has been used to simulate the path-loss from a mobile terminal to a sensor for three mobile communication standards. The results show the PMD coverage for GSM 900 and GSM 1800 is considerably large while for UMTS it is much smaller. A pure energy detector is thus clearly insufficient for UMTS and demodulating the signals was suggested in order to improve the SNR by exploiting the processing gain of CDMA system.

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