Chapter 7
Efficient Discrete Simulation of Coded Wireless Communication Systems

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ABSTRACT

Simulation can be a valuable tool for wireless communication system's (WCS) designers to assess the performance of its radio interface. It is common to use the Monte Carlo simulation method (MCSM), although this is quite time inefficient, especially when it involves forward error correction (FEC) with very low bit error ratio (BER). New techniques were developed to efficiently evaluate the performance of the new class of TCH (Tomlinson, Cercas, Hughes) codes in an additive white Gaussian noise (AWGN) channel, due to their potential range of applications. These techniques were previously applied using a satellite channel model developed by Lutz with very good results. In this chapter, we present a simulation method, named accelerated simulation method (ASM), that provides a high degree of efficiency and accuracy, namely for lower BER, where the application of methods like the MCSM is prohibitive, due to high computational and time requirements. The present work generalizes the application of the ASM to a WCS modelled as a stochastic discrete channel model, considering a real channel, where there are several random effects that result in random energy fluctuations of the received symbols. The performance of the coded WCS is assessed efficiently, with soft-decision (SD) and hard-decision (HD) decoding. We show that this new method already achieves a time efficiency of two or three orders of magnitude for SD and HD, considering a $\mathrm{BER} = 1 \times 10^{-4}$*, when compared to MCSM. The presented performance results are compared with the MCSM, to check its accuracy.*

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EFFICIENT DISCRETE SIMULATION OF CODED WIRELESS COMMUNICATION SYSTEMS

Modern communications are already part of everyone's life. Technologies such as wireless fidelity (Wi-Fi), universal mobile telecommunications system (UMTS) and its developing long term evolution (LTE), and worldwide interoperability for microwave access (WiMAX) are already familiar. For regions of the globe where these technologies are not yet implemented, new interface radio systems are being deployed using satellites, so as to allow the use of common wireless systems anywhere and anytime, that is, a global communications system.

Whatever the radio systems may be, they all have one aspect in common: prior to implementation, several studies must be done to assess the performance of its radio interface. It is common to use the Monte Carlo simulation method (MCSM) to evaluate the system's performance including some or all of its radio interface components, such as scrambling, coding, modulation, filtering, channel effects and all of its counterparts at the receiver. Depending on the required accuracy, this is usually quite a time consuming task, even when high computational systems are used. This situation gets even worse when systems involve forward error correction (FEC) with very low bit error ratios (BER), typically less than 10^{-6}.

As an alternative to MCSM, there are several techniques described in the literature which can help to shorten this time consuming task. One of the most efficient techniques is the importance sampling (IS) technique; however this has the disadvantage that it is only applicable to some particular cases, and cannot be generalized for a wider range of applications (Jeruchim, Balaban & Shanmugan, 2000, pp. 710-737). An important contribution to solve this problem has been given by (Bian, Poplewell & O'Reilly 1994) who optimised some simulation techniques in order to evaluate the performance of coded communication systems at low BER in an additive white Gaussian noise (AWGN) channel. Based on that work, new techniques were developed to evaluate the performance of block codes in an AWGN channel, in a very efficient way (Cercas, Cartaxo & Sebastião, 1999) They were also applied to a satellite channel model developed by Lutz, Cygan, Dippold, Dolainsky & Papke, (1991) obtaining very good agreement with the foreseen upper bounds of some FEC schemes performance (Sebastião, Cercas & Cartaxo, 2002).

In this chapter, we present a new simulation method named accelerated simulation method (ASM) since it can provide a high degree of efficiency when compared with the MCSM, which increases for very low BER, while maintaining very good accuracy.

This method can be applied to communication systems with hard-decision (HD) and soft-decision (SD) decoding, in a more realistic channel model.

In this chapter, the ASM was applied to compute the performance of the new class of Tomlinson, Cercas, Hughes (TCH) codes. These codes are a class of non-linear block codes that were devised for a wide range of applications, including FEC. These codes exhibit good performance and undertake maximum likelihood soft-decision decoding with a very simple decoder structure, using digital signal processing techniques and correlation in the frequency domain. Furthermore, they can be used simultaneously in code division multiple access (CDMA), channel estimation and synchronization of the receiver, due to the very good correlation properties of its code words (Cercas, Tomlinson & Albuquerque, 1993).

The main contribution of this chapter is the generalization of the ASM method to a more realistic channel model. Real channels are far more complex than AWGN ones, as the signal is also affected by other effects such as multipath components with different delays and other interference phenomena that result in random energy fluctuations of the received symbols, that is, the