A Simulation Environment for Concatenated and Turbo Codes Analysis and Optimization

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The evaluation of the transmission reliability plays a fundamental role in the design of wireless or aerospace communication systems. In order to face this request simulation environments provide a modeling-design-analysis [1] process that allow to simulate the behavior of coded transmissions [2], [3] and [4] over different kind of noisy channels.

This paper is aimed at presenting the simulation environment, called SatComSE, that has been developed to study the influence of errors on concatenated and turbo coded transmissions [5], [6], [7], [8] and [9] in order to optimize the characteristics of the code according to the noise conditions. In principle in order to perform the optimization of a generic communication system, an analytical description of the problem should be found, an objective function that represents an explicit relationship between input parameters and performances should be defined, and this objective function should be optimized with one of operational research techniques. In practice this approach can be applied only to idealized and oversimplified cases due to the difficulty to find both the analytical description and the objective function in complex communication systems. For this reason, as also suggested by the European Space Agency [10], the evaluation of the reliability of generic communication systems definitively needs to be performed through the simulation of the communication system itself.

SatComSE performs the simulation of the selected communication system through the following steps:

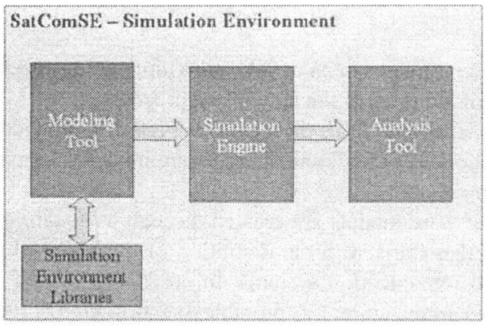

Figure 1: SatComSE Architecture

1. Modeling of the communication system
2. Simulation of the modeled communication system
3. Visualization and analysis of the simulation results

The SatComSE simulation environment, which has been developed with Matlab, is composed of three tools (as presented in Figure 1):

- Modeling Tool
- Simulation Engine
- Analysis Tool

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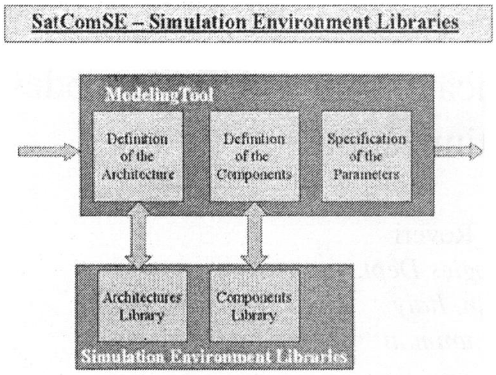

Figure 2: The Modeling Tool

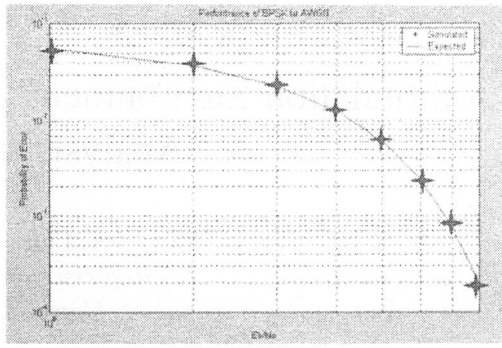

Figure 3: BPSK simulated and expected results comparison

Each tool has been developed with the aim to perform one of the steps of the simulation process.
The *Modeling Tool*, presented in Figure 2, provides the functionalities to define the software model of communication systems.

Software models are created through a *Modeling Process* that starts with the definition of the architecture of the communication system. In order to specify the selected architecture, it is possible to choose one of the predefined architectures present in the *Architectures Library* of the SatComSE simulation environment or to select a user-defined architecture inserted in the system through the *Add a New Architecture* functionality of the Modeling Tool.
The second step of the Modeling Process is the definition of the components that belong to the chosen architecture. Even in this case it is possible to select each specific component from the *Component Library* of the SatComSE or to insert user-defined components inserted in the system through the *Add a New Component* functionality of the Modeling Tool.
The last step of the Modeling Process is the specification of the parameters of the components identified in the previous step.

The *Simulation Engine*, which is the core of the Simulation Environment, is aimed at performing the proper simulation of the modeled communication system. It receives in input a model of the system and produces in output the results of the simulation according to the simulation parameters specified by the user.
It is possible to specify the requested degree of reliability of the simulation results through the selection of one of the three available simulation algorithms.
In order to perform the simulation, the Simulation Engine inserts the modeled system in an ad-hoc environment to evaluate its performances respect to different levels of noise. The results are calculated through the comparison between the transmitted and the received information at a fixed signal-to-noise ratio.
The results of the simulation are then stored in the *Simulation Results Archive* through the *Storage Service*.

The last step of the simulation process is performed by the *Analysis Tool* that allows to represent the simulation results and to perform comparisons among different simulation results or validations of the results themselves.

The developed environment has then been applied to some real cases both to show the functionalities it can offer, and to analyze and validate the simulation results.
As presented in figure 3, the results of the simulation of uncoded BPSK transmissions over an AWGN channel showed an high level of closeness with the values expected in literature for this kind of transmission.

The simulation of two different Reed Solomon codes over the same AWGN channel showed, as expected, that the RS(15,7) overcomes the performances of the RS(15,11).
The increasing of the performances due to the use of soft

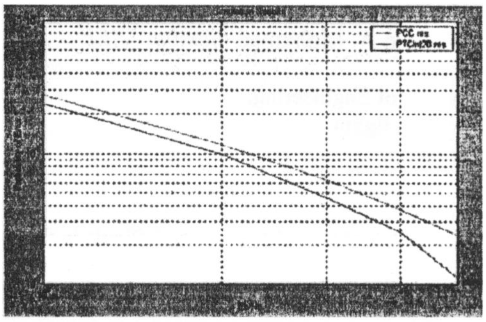

Figure 4: Parallel Concatenated code (upper line) and Parallel Turbo code comparison (lower line)

instead of hard decoding has then be simulated with SatComSE. The results of these simulations have shown, as expected, the great advantage, in terms of reliability, which soft decoding techniques can offer to convolutional codes in noisy channels.
The advantages of the use of concatenated instead of single codes has then be showed in a set of simulations performed with SatComSE.
A comparison between two concatenated codes simulated with SatComSE showed that a RS code concatenated with a soft decoding convolutional code allows higher performances than the same RS code concatenated with an hard decoding convolutional code.
The effects of the presence of the interleaving component and the relationship between interleaving design and performances in coded transmissions over a channel corrupted by impulse noise have been evaluated through the simulations of two parallel turbo codes and a parallel concatenated code. These simulations showed that, due to the presence of the interleaver component, turbo coded transmissions behave better than concatenated one in this kind of channel. The graphical comparison of these simulations is presented in Figure 4.

The developed environment has been thought of as a tool to support both the research and the study on concatenated and turbo codes, and the development of industrial applications.
Future developments could be the development of new and more detailed components and the possibility to enrich the Simulation Environment with an Optimization Tool (based on Operative Research Techniques) in which the objective function is not analytically evaluated but is experimentally calculated.

References

[1] Michel C. Jeruchim, Philip Balaban, and K. Sam Shanmugan, *Simulation of Communication Systems*, Plenum Press. New York, 1992.

[2] Arnold M. Michelson and Allen H. Levesque, *Error-Control Techniques for Digital Communication*, John Wiley and Sons, 1985.

[3] William W Wu, *Elements of Digital Satellite Communication - Volume II*, Computer Science Press, 1995.

[4] Consultive Committee for Space Data Systems (CCSDS), *Telemetry Channel Coding*, 1999.

[5] Claude Berrou, Alain Glavieux, and Punya Thitimajshima, "Near shannon limit error-correcting coding and decoding: Turbo codes," *IEEE Transaction*, 1993.

[6] S. Adrian Barbalescu, "Turbo codes: a tutorial on a new class of powerful error correcting coding schemes (part i)," *Institute for Telecommunications Research University of South Australia*, 1998.

[7] S. Adrian Barbalescu, "Turbo codes: a tutorial on a new class of powerful error correcting coding schemes (part ii)," *Institute for Telecommunications Research University of South Australia*, 1998.

[8] Jakob Dahl Andersen, "A turbo tutorial," *Technical University of Denmark*, 1995.

[9] Matthew C. Valenti, "Iterative detection and decoding for wirless communication," *Virginia Polytechnic Institute and State University*, 1999.

[10] European Space Agency, *Advanced Decoding Algorithms for Satellite Broadcasting*, 2000.