SOFTWARE SIMULATION TOOLS ON FORWARD ERROR CORRECTION SCHEMES FOR THE WIRELESS TRANSMISSION OF MPEG-4 AAC AUDIO BITSTREAMS

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ABSTRACT

In this paper, software tools which simulate the error correcting capability of forward error correction (FEC) codes, for the transmission of MPEG Advanced Audio Coding (AAC) bitstreams over a wireless channel, are described. The tools consist of two applications. The first application is a channel transmission simulator with the features to set the choice of FEC codes, wireless channel characteristics and observe the simulation results. The second application is a graph plotting software that facilitates analysis of simulation results. Such a tool makes it convenient to investigate the transmission of audio data over wireless links.

1. INTRODUCTION

To facilitate convenient experimentation to learn and appreciate the usefulness of Forward Error Correction (FEC) schemes in correcting bit errors that occur in a MPEG-AAC audio file during wireless transmission, a set of simulation tools is designed.

This set of tools has two purposes. First, it allows one to carry out simulations of the transmission of an audio file over a wireless channel using different FEC schemes. Second, it can plot and compare the results of these simulations. This set of tools is aimed at users who are undergoing courses in digital communications or coding theory, and have some prior knowledge on the basics of a typical communications system and FEC schemes. The users are not required to have extensive knowledge of programming languages in order to carry out the simulations and observe the results.

This set of simulation tools is explained in detail in the following sections. In Section 2, the basic principles of FEC schemes for audio data and the factors that can be used to measure their performances are presented. Section 3 describes in detail the set of simulation tools, its purposes and how it can be used. Section 4 gives examples of simulation results. Conclusions are drawn in Section 5.

2. PRINCIPLES OF FEC IN AUDIO BITSTREAM

Reliable transmission of high fidelity digital compressed audio data, MPEG-AAC, over wireless links, is an important application requirement. Bit errors introduced into the bitstream may cause the audio file to be un-decodable at the receiver, resulting in a loss of quality. FEC codes are introduced into the digitally-coded data to protect it from channel errors during transmission. This reduces the need for re-transmission of data. To reduce the amount of redundancy introduced by these FEC codes, Unequal Error Protection (UEP) is also implemented whereby different degrees of error protection are introduced to different data partitions, based on the bit error sensitivity of the data to channel impairments.

2.1. FEC Schemes for MPEG-AAC

For MPEG-AAC, various FEC schemes, with UEP, have been proposed. One such scheme is the Error Protection Tool (EP Tool), by NTT DoCoMo, based on Hard Decision Convolutional Codes [1]. Other techniques include Soft Decision Convolutional Codes [2], Reed Solomon Codes, Reed Solomon Codes serially concatenated with Hard Decision Convolutional Codes [3], and Turbo Product Codes concatenated with Soft Decision Convolutional Codes [4].

The audio data is first classified and partitioned into classes. Data such as Header information and Class 1 bits, which are more sensitive to channel impairments, are given more protection (more parity bits). Other classes, such as Class 2 bits and Class 3 bits, are given less protection, thereby reducing the overall redundancy. More detailed description of the classification of the MPEG-AAC bitstream can be found in [5].

2.2. Evaluation of Performance of FEC Schemes

The relative performance of these FEC schemes can be determined by three factors.

The first factor is the residual bit error rate (BER) of the overall MPEG-AAC bitstream versus the channel Signal-to-Noise Ratio (SNR): a low residual BER indicates good performance by the FEC scheme. However, this factor has a limitation. An audio bitstream with more erroneous bits may sound better than another with a smaller number of error bits. This is because the erroneous bits may be concentrated in the less important classes of bits for the former bitstream.

The second factor is the average CPU processing time taken by decoding and correcting the errors in the data: a short processing time indicates low complexity by the FEC scheme. The third factor is the average redundancy introduced by these FEC schemes during coding: a small amount of redundancy compared to the amount of data is desired to preserve efficient bandwidth transmission.

3. SIMULATION TOOLS

The simulation tools comprise two main components:

- AAC Simulator Software: It allows users to run simulations of transmission of MPEG-AAC data over a wireless channel, using different FEC schemes.
- Graph Plotting Software: It allows users to plot and compare the BER versus SNR graphs of the FEC schemes.

3.1 AAC Simulator Software

The AAC Simulator is programmed using Visual C++, which has a Graphical User Interface (GUI) in Figure 1.

This software is used as follows. Firstly, a user selects an audio file in .au format to be imported for the simulations. The audio file is converted into a data-partitioned bitstream by a MPEG-4 AAC encoder. The FEC scheme is chosen. There are five schemes currently implemented in this software: Hard Decision Convolutional Codes, Soft Decision Convolutional Codes, Reed Solomon Codes, Reed Solomon Codes concatenated with Soft Decision Convolutional Codes and finally Turbo Product Codes concatenated with Soft Decision Convolutional Codes. This software can be modified to accommodate more FEC schemes in the future.

Next, the channel model is chosen. Two channel models are implemented: An Additive White Gaussian Noise (AWGN) channel model or a Rician Fading channel model, whose parameters can be modified later.

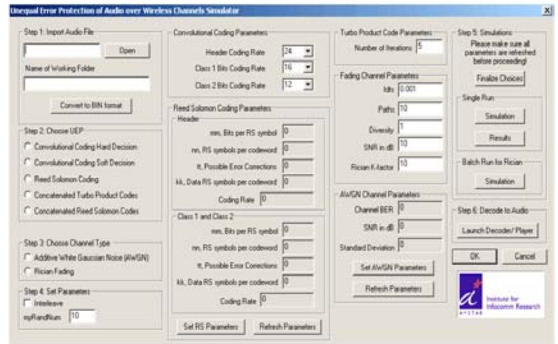

Figure 1: GUI for AAC Simulator

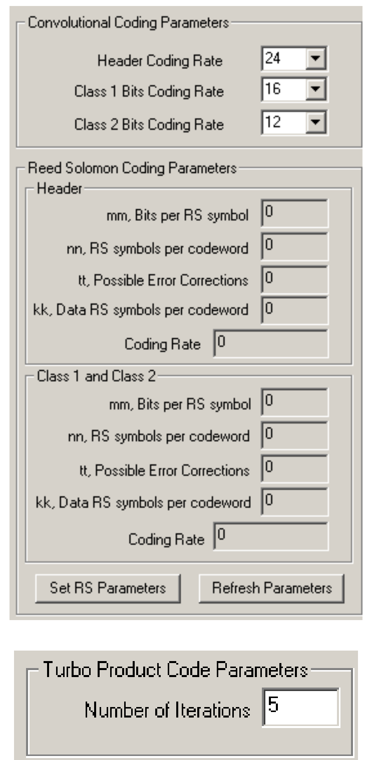

Figure 2: Setting Parameters for the FEC Schemes

There is an option to include interleaving in the simulations. The bits are interleaved in a way such that burst errors appear to be random. The decoder is less likely to make decision errors when bit errors are random.

Next, the parameters of the respective FEC schemes can be customized. Figure 2 shows the section where the user can customize the settings for the FEC schemes: the degree of protection, the code rate and the number of errors that can be corrected.

Next, depending on the channel model selected, the parameters of the Rician Fading channel or the AWGN channel as shown in Figure 3, are set.

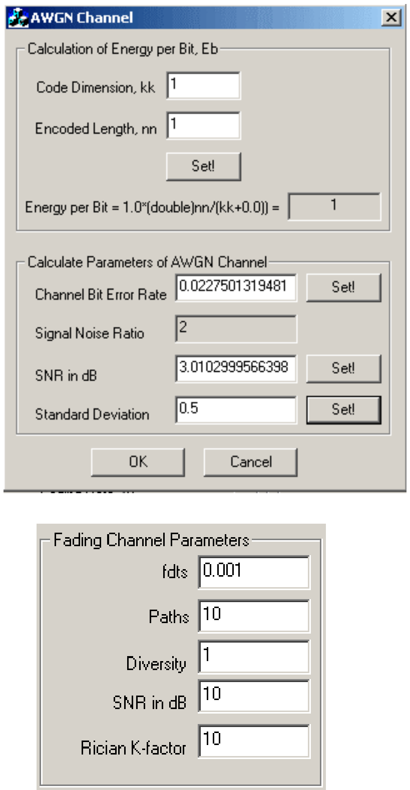

Figure 3: Setting Parameters for the AWGN and Rician Fading Channel respectively

The type of simulation is then set. Two types of simulation can be selected, either a single run which simulates one round of FEC coding with only one set of parameters, or a batch run which can execute up to ten rounds of FEC coding with different sets of parameters. However the batch run feature currently supports only simulations under the Rician Fading Channel.

The results of the simulations are shown in the dialog box in Figure 4. The name of the audio file, FEC schemes used and the channel model used is logged into this box. In addition, the average redundancy in percentage and the bit error statistics are also recorded.

Finally, an audio decoder/ player as shown in Figure 5 can be launched, which can decode the MPEG-AAC bitstream, play the original audio file and the decoded audio file. The user can discern the differences in quality between the original and the decoded file.

3.2 Graph Plotting Software

This software is designed using GUI tools within MATLAB as shown in Figure 6. It can be used to plot BER versus SNR graphs of the various FEC schemes after the results of the simulations are recorded.

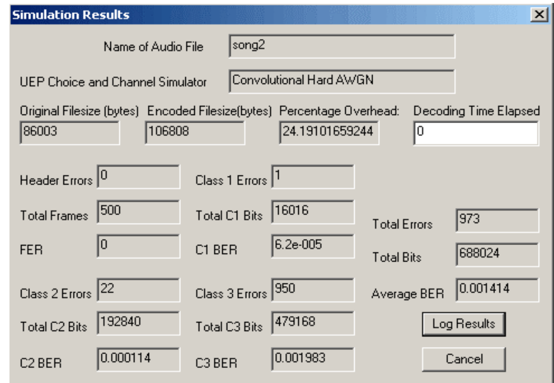

Figure 4: Simulation Results Dialog Box

Figure 5: Audio Decoder/ Player

This software has the following features:

- It allows the user to input x-y values or import x-y values from external text files.
- It can draw 4 types of graphs, i.e. normal axis graphs, semilog graphs with either x-axis or y-axis in logarithmic form, or log-log graphs.
- It allows the user to state the title, edit the plot, and export the plot to jpeg, bitmap images.

4. EXAMPLES OF SIMULATION RESULTS

Figure 7 gives an example of a BER versus SNR graph under a Rician fading channel, after using the AAC Simulator software to obtain the numerical results and the Graph Plotting software to obtain the plots. In this particular example, the Reed Solomon Codes concatenated with Convolutional Codes and the Turbo Product Codes concatenated with Convolutional Codes provide the lowest BER versus SNR graph relative to the other schemes. The feature of the average redundancy introduced by FEC codes in each class will be added in the future.

The CPU average processing time is recorded and compared in Figure 8. The Soft Decision Convolutional Codes have the highest CPU processing time while the concatenated codes have a low CPU processing time.

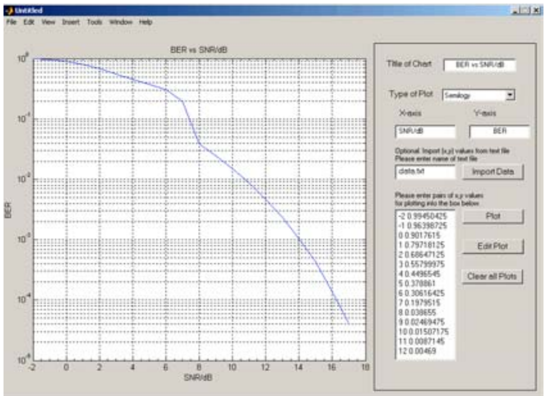

Figure 6: Graph Plotting Software GUI

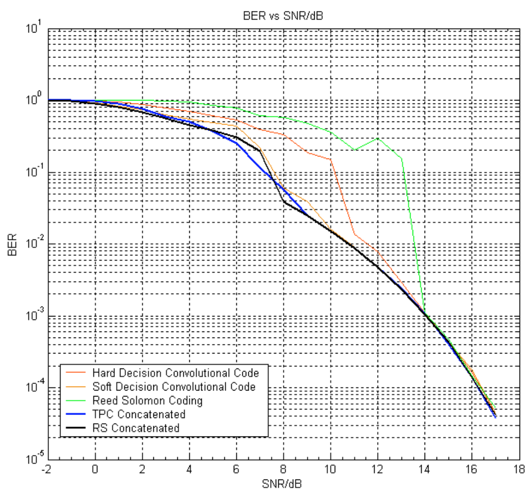

Figure 7: Simulation Results

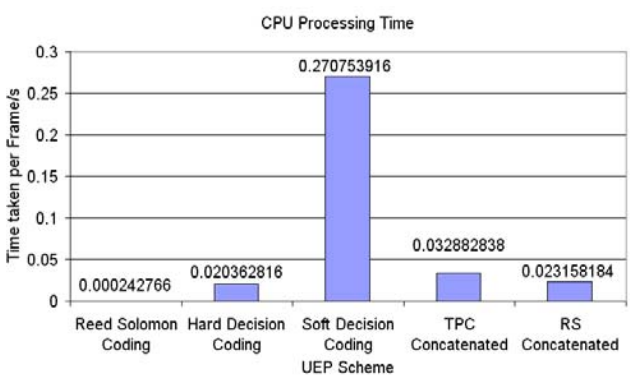

Figure 8: CPU Processing Time of FEC Schemes

Figure 9 shows an example of the average redundancy introduced by the FEC schemes to the audio file. The average percentage overhead is calculated as:

$$\text{Percentage Overhead} = \frac{\text{Encoded Filesize - Original Filesize}}{\text{Original Filesize}} \times 100\%$$

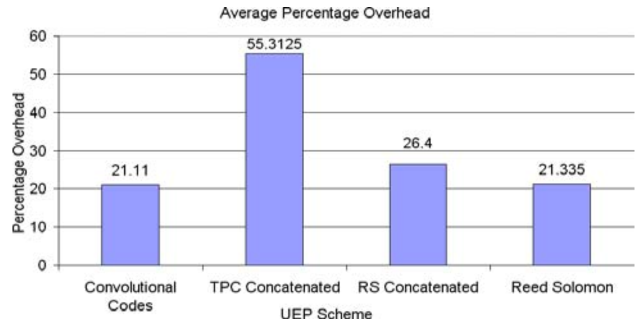

Figure 9: Average Redundancy of FEC Schemes

In this example, the Turbo Product Codes add the most redundancy whereas all the other schemes have much lower redundancy.

5. CONCLUSION

In this paper, a set of software tools, which carries out the simulation of the error correcting capabilities of FEC UEP schemes for the wireless transmission of the MPEG-AAC bitstream, is described. It is aimed at users who are undergoing courses in digital communications or coding theory. By using these tools, they can determine and compare the performance of these FEC schemes and thus learn and appreciate the importance of FEC schemes in an everyday wired or wireless multimedia transmission application.

6. REFERENCES

[1] R. Sperschneider, M. Dietz and T. Miki, *MPEG-4 Audio Error Resilience Work Plan,* ISO/IEC JTC1/SC29/WG11, Update of 45th meeting, Seoul, October 1998

[2] T.H. Yeo, W.C. Wong, D.Y. Huang, *Soft Decision Unequal Error Protection Scheme for MPEG Advanced Audio Coding.* ICME July 6-9, 2003. Baltimore MD, U.S.A. CD-ROM.

[3] D.Y. Huang, S.W. Foo, W.S. Lin, J.N. Al Lee, *Application of a Concatenated Coding System with Convolutional Codes and Reed-Solomon Codes to MPEG Advanced Audio Coding*, AES 113th Convention, Los Angeles, California, USA, 2002, preprint 5682.

[4] T.H. Yeo, W.C. Wong, D.Y. Huang, *Robust MPEG Advanced Audio Coding over Wireless Channels,* AES 115th convention, New York, USA, 2003, preprint 5869.

[5] *Information Technology – Coding of Audiovisual Objects Part 3: Audio, Subpart 6: Error Protection,* WD 14496-3 Amd 1 Subpart 6, ISO/JTC 1/SC 29/WG11

[6] J.G. Proakis and M. Salehi, *Communications System Engineering*, Prentice Hall, 2002

[7] S.B Wicker, *Error Control Systems for Digital Communication and Storage*, Prentice Hall, Edition:1e