PERFORMANCE ANALYSIS IN TERM BIT ERROR RATE (BER) ON DECODING ALGORITHM OF TURBO CODES

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To my beloved mother and father

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Abstract

This project focuses on the turbo codes decoding algorithm whose performance in terms of Bit Error Rate (BER) are close to the SHANNON limits. Soft Output Viterbi Algorithm (SOVA) and Log-Maximum A Posteriori (Log-MAP) turbo decoding algorithms are the two prime candidates for decoding turbo codes. This project used both of decoding algorithm. SOVA and Log-MAP turbo decoder are share common operations, making feasible a reconfigurable for reduced power consumption. Using a common scaling factor in the extrinsic information calculation of both algorithms can improve performance with minimal effort. The scaling factor is independent of the signal to noise ratio. Some explanation of the code performance and sheds some light on the relative importance of the code ingredients with particular emphasis on interleaving and puncturing in this report. Besides, this project are to compare the performance analysis in terms of Bit Error Rate (BER) by using two different decoding SOVA and Log-MAP. This project used the frame size (N), generator matrix (g), code rate (r) and number of iteration as parameter in the decoding process to get the results. Thus, the effect of varying the parameter on the error-correcting capability of the code can be readily investigated by changed the values of each parameter. It is also shown that the MAP algorithm gives a better error performance than the SOVA decoder under similar conditions. The simulation work is done by using a MALAB simulation platform.

Abstrak

Projek ini lebih tertumpu kepada penyahkod algoritma untuk „Turbo Codes‟ di mana prestasinya didalam terma kadar kesalahan bit adalah menyamai kepada had „SHANNON‟. „Soft Output Viterbi Algorithm (SOVA)‟ dan „Log-Maximum a Posteriori (Log-MAP)‟ penyahkod algoritma turbo adalah dua pilihan utama untuk menyahkod „Turbo Codes‟. Projek ini menggunakan kedua-dua pilihan tesebut. Kedua-duanya berkongsi operasi asas yang sama, membuatkan ia sesuai untuk dikonfigurasikan oleh SOVA dan Log-MAP penyahkod turbo untuk mengurangkan penggunaan tenaga. Penggunaan faktor pengskalaan yang sama dalam pengiraan maklumat ekstrinsik yang sama untuk kedua-dua algoritma akan memnambahkan prestasi dengan sedikit usaha. Faktor pengskalaan itu tidak bergantung kepada nisbah isyarat hingar. Laporan projek ini memberikan sedikit penjelasan kepada prestasi kod dan juga kepentingan relatif terhadap kandungan kod dengan penekanan kepada pengulangan dan penusukan. Selain itu juga, projek ini adalah analisis untuk membandingkan prestasi dalam terma kadar kesalahan bit dengan menggunakan dua penyahkod berbeza iaitu SOVA dan Log-MAP. Projek ini mengunakan saiz kerangka(N), matrik penjana(g), kadar kod(r), dan jumlah pengulangannya sebagai parameter di dalam proses penyahkod untuk mendapatkan keputusan yang baik. Oleh yang demikian, kesan daripada mempelbagaikan parameter kepada kebolehan memperbetulkan kesalahan kod boleh dianalisa dengan mengubah nilai setiap parameter dan juga ditunjukkan, algoritma MAP memberikan prestasi kesalahan yang lebih baik daripada penyahkod SOVA dalam keadaan yang sama. Perisian MATLAB digunakan untuk simulasi penyahkod.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

1.1 Project Background

Turbo codes are perhaps the most exciting and potentially important development in coding theory in recent years. They achieve near-Shannon-limit error correction performance with relatively simple component codes and large interleavers. They can be constructed by concatenating at least two component codes in a parallel fashion, separated by an interleaver. One feature of turbo codes is the constituent codes need not be complex. In order for a concatenated scheme such as a turbo code to work properly, the decoding algorithm must effect an exchange of soft information between component decoders. The concept behind turbo decoding is to pass soft information from the output of one decoder to the input of the succeeding one, and to iterate this process several times to produce better decisions. Iterative decoding of turbo codes can be realized using either two different decoding algorithm, namely the Log-Maximum A Posteriori (Log-MAP) algorithm or the Soft Output Viterbi Algorithm (SOVA).

This report project is presents a project which consists of a study of turbo codes as an error- control code and the software implementation of two different decoding algorithms which is Log-Maximum A Posteriori (Log-MAP) algorithm or the Soft Output Viterbi Algorithm (SOVA). The project is to investigate and compare the performance analysis in terms of Bit Error Rate (BER) by using two different decoding that was applied in turbo codes.

1.2 Project Objective

The objectives of this project are shown below:

i. To carry out an invstigate of turbo codes.
ii. To compare the performance analysis in terms of Bit Error Rate (BER) by using two different decoding, Soft Output Viterbi Algorithm (SOVA) and Log-Maximum A Posteriori(Log-MAP).
iii. Be able to use MATLAB sotware and understanding the programming.
iv. To analyze the performance of the Bit Error Rate by using Soft Output Viterbi Algorithm (SOVA) and Log-Maximum A Posteriori(Log-MAP) decoding

1.3 Problem Statement

In channel coding, redundancy is introduced in the information sequence in order to increase its reliability. The channel coding theorem state that is even at relatively low Eb/No reliable communication can still be maintained. However, the theorem tells us nothing about how to design the code that achieves such performance. All what it says is that the code should appear random. Unfortunately random codes are very difficult to decode. Some structure in the code is needed to make the decoding feasible. So turbo codes is introduced as a new technique of error correction coding way to change current other codes.

1.4 Scope of Project

As we are concern with scopes of work while doing the project, so it must be create properly. There must be a guideline, in which the student should attain, but yet never go beyond is as to fulfill the requirement of the project. A Scope of work as listed below:

i. By using the software such as MATLAB, the expected result for performance analysis in terms of Bit Error Rate (BER) can be earned. Simulation process is one of the engineering methods to get the expected result without using any material that costly.
ii. The comparison between two different decoding, Soft Output Viterbi Algorithm (SOVA) and Log-Maximum A Posteriori (Log-MAP). From this comparison we can know and choose which decoding is better used in terms of Bit Error Rate (BER) that always applied in Turbo Codes.

1.5 project Methodology

Phase 1 :

Collect all information and undertand about Turbo Codes and any sofware that could be used for calculation, simulation, optimization and comparing of result.

Phase 2 :

Start to construct the program by using MATLAB software with theoretical analysis of Turbo Code.

Phase 3 :

By using MATLAB compile, simulate and synthesis the program for two method, SOVA and Log-Map

Phase 4 :

Compare of result based on theorical and simulation.

Phase 5 :

Choose the best result between the two methods

1.6 Report Structure

This report consists of chapters that will explain and discuss more details about this project. Divided into 5 chapters. The first chapter gives a brief explaination about Turbo Codes. It also gives an introduction about the overall process of project.

The second chapter is about the literature review of the project. Background knowledge of Turbo Codes studied in order to understand the performance analysis in terms of Bit Error Rate (BER) that always applied in Turbo Codes by using two different decoding, Soft Output Viterbi Algorithm (SOVA) and Log-Maximum A Posteriori (Log-MAP).

The third chapter is about research mythology which explained about method used and process involved in the project.

The fourth chapter is about the result. All the data and the last results that obtained during this semester will be documented in this chapter.

The fifth chapter is discussion and conclusion for this project including the recent progress of work.

CHAPTER II

LITERATURE REVIEW

2.1 Introduction

This chapter will discuss about the information obtained from findings and any useful sources. Information from the literature review are very important as a background of Turbo Codes.

2.2 Turbo Codes

Turbo codes were first introduced in 1993 by Berrou, Glavieux, and Thitimajshima, and where a scheme is described that achieves a bit-error probability of 10^{-5} using a rate 1/2 code over an additive white Gaussiannoise (AWGN) channel [1]. The codes are constructed by using two or more component codes on different interleaved versions of the same information sequence. Whereas, for conventional codes, the final step at the decoder yields hard-decision decoded, for a concatenated scheme such as a turbo code to work properly, the decoding algorithm should not limit itself to passing hard decisions among the decoders. To best exploit the information learned from each decoder, the decoding algorithm must effect an exchange of soft decisions rather than hard decisions. For a system with two component codes, the concept behind turbo decoding is to pass soft decisions from the output of one decoder to the input of the other decoder, and to iterate this process several times so as to produce more reliable decisions [9].

The BER performance of a typical turbo code used with the iterative turbo decoding algorithm. The proximity to the rate-specific Shannon bound varies with the information length N, with the choice of constituent encoders and interleaver, and with details of implementation of the decoding algorithms. However, over the range of such varying parameters, the curves display the characteristics as shown: There is a plateau region at very low SNR, where there is little or no improvement over uncoded transmission; followed by the waterfall region, where the BER drops off rapidly with increasing SNR. Finally there is an error floor at higher SNR, where the BER mainly depends on the probability of decoding to a few most likely error vectors [1].

2.3 Structure of a Turbo Code

According to Shannon, the ultimate code would be one where a message is sent infinite times, each time shuffled randomly. The receiver has an infinite version of the message albeit corrupted randomly. From these copies, the decoder would be able to decode with near error-free probability the message sent [2]. This is the theory of an ultimate code, the one that can correct all errors for a virtually signal.

Turbo code is a step in that direction. But it turns out that for an acceptable performance we do not really need to send the information infinite number of times, just two or three times provides pretty decent results for our earthly channels [8].

In Turbo codes, particularly the parallel structure, Recursive systematic convolution (RSC) codes working in parallel are used to create the "random" versions of the message. The parallel structure uses two or more RSC codes, each with a different interleaved. The purpose of the interleaver is to offer each encoder an uncorrelated or a "random" version of the information, resulting in parity bits from each RSC that are independent. How “independent” these parity bits are, is essentially a function of the type and length/depth of the interleaver. The design of interleaver in itself is a science. In a typical Viterbi code, the messages are decoded in blocks of only about 200 bits or so, where as in Turbo coding the blocks are on the order of 16K bits long. The reason for this length is to effectively randomize the sequence going to the second encoder. The longer the block length, the better is its correlation with the message from the first encoder, i.e. the correlation is low [8].

On the receiving side, there are same number of decoders as on the encoder side, each working on the same information and an independent set of parity bit. This type of structure is called Parallel Concatenated Convolutional Code or PCCC [8].

The convolutional codes used in turbo codes usually have small constraint length. Where a longer constraint length is an advantage in stand-alone convolutional codes, it does not lead to better performance in TC and increases computation complexity and delay. The codes in PCCC must be RSC. The RSC property allows the use of systematic bit as a standard to which the independent parity bits from the different coders are used to assess its reliability. The decoding most often applied is an iterative form of decoding [8].

When we have two such codes, the signal produced is rate 1/3. If there are three encoders, then the rate is ¼ and so on. Usually two encoders are enough as increasing the number of encoders reduces bandwidth efficiency and does not buy proportionate increase in performance.

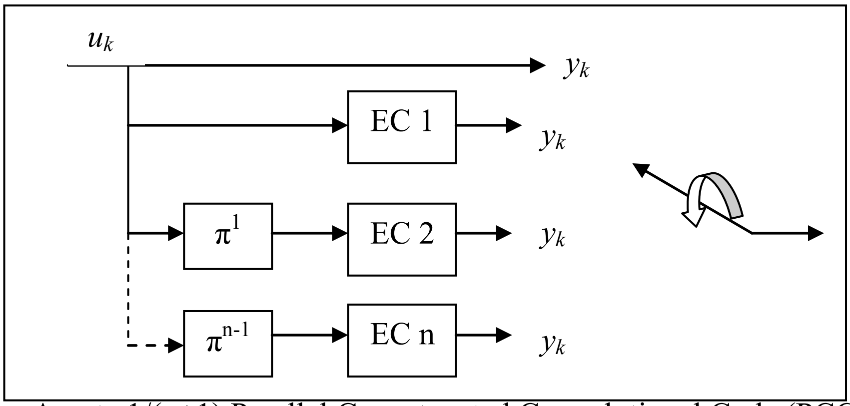

Figure 2.3.1 A rate 1/(n+1) Parallel Concatenated Convolutional Code (PCC) Turbo Code

Turbo codes also come as Serial Concatenated Convolutional Code or SCCC. The SCCC codes appear to have better performance at higher SNRs. Where the PCCC codes require both constituent codes to be RSC, in SCCC, only the inner code must be RSC. PCCC codes also seem to have a flattening of performance around 10-6 which is less evident in SCCC. The SCCC constituent code rates can also be different as shown below. The outer code can even be a block code [3].

In general the PCCC is a special form of SCCC. We can even think of concatenation of RS/Convolutional codes, used in line-of-sight links as a form of SCCC. A Turbo SCCC may look like the figure below with different rate constituent codes.

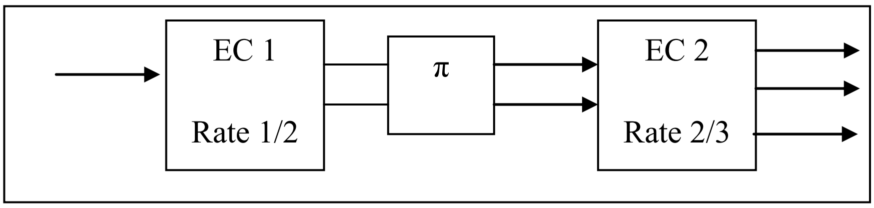

Figure 2.3.2 Serially concatenated constituent coding (SCCC)

Then there are also hybrid versions that use both PCCC and SCCC such as shown in figure below.

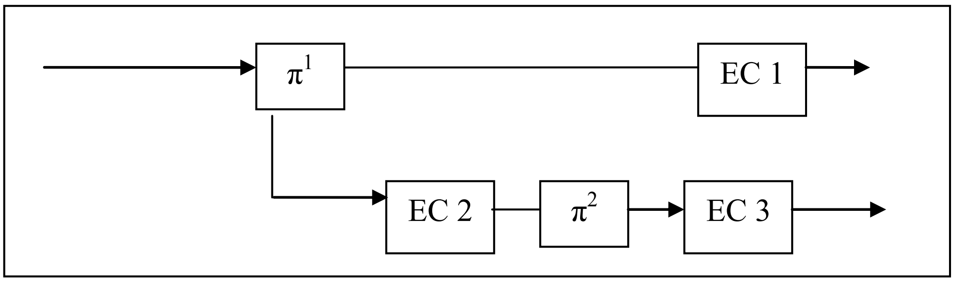

Figure 2.3.3 Hybrid Turbo Codes

There is another form called Turbo Product Code or TPC. This form has a very different structure from the PCCC or SCCC. TPC use block codes instead of convolutional codes. Two different block codes (usually Hamming codes) are concatenated serially without an interleaver in between. Since the two codes are independent and operate in rows and columns, this alone offers enough randomization that no interleaver is required. TPC codes, like PCCC also perform well in low SNR and can be formed by concatenating any type of block codes. Typical coding method is to array the coded data in rows and then the second code uses the columns of the new data for its coding. The following shows a TPC code created from a (7x5) and a (8x4) Hamming code. The 8x4 code first codes the 4 info bits into 8, by adding 4 p1 party bits. These are arrayed in five rows. Then the 7x5 code works on these in columns and creates (in this case, both codes are systematic) new parity bits p2 for each column. The net code rate is 5/14 ~ 0.33. The decoding is done along rows and then columns [3].

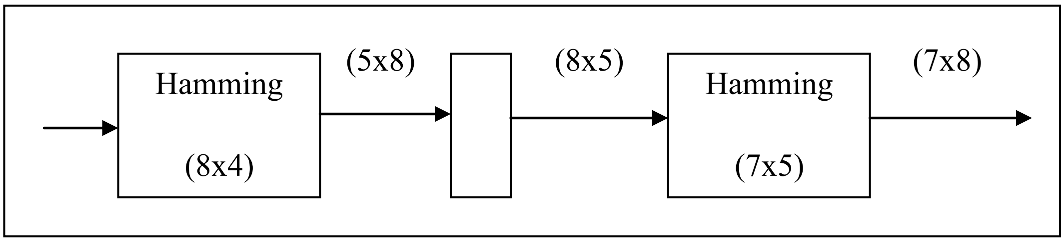

Figure 2.3.4 Turbo Product codes

I	I	i	I	p1	p1	p1	p1