Performance Analysis for various parameters in Decoding of Asymmetric Turbo Codes

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Abstract
The performance of the asymmetric turbo codes can be improved by varying different parameters such as block length, code rate, component polynomial structure and number of iterations. This paper proposes two types of asymmetric turbo codes that consists of parallel concatenated turbo codes that uses non-identical recursive systematic component encoders with mixed type generator polynomials and different constraint lengths. The proposed scheme optimizes the BER performance of both water fall region at low SNR and error-floor region at high SNR. The simulation results shows better BER performance of asymmetric turbo codes than the conventional symmetric system over entire range of SNR with a reduced decoding computational complexity. The simulation model was developed by using MATLAB.

Keywords: Asymmetric Turbo Codes, Bit Error Rate, Constraint Length, Error-Floor and Waterfall

1 Introduction
In 1993, turbo codes are introduced by Berrou, Glavieux and Thitimajshima. These codes are introduced as one of the most powerful error control codes and also excellent coding gain. Which were the first practical codes to closely approach the channel capacity. Due to many research efforts of the turbo coding community, it is used in standard system such as third-generation (3G) mobile radio system and so many other emerging wireless applications. Asymmetric turbo codes are basically constructed by two or more parallel Recursive Systematic Convolutional (RSC) codes, which are linked by a pseudo-random interleaver [1][3]. Basically, the turbo codes can be divided into two types based on their generator polynomial structures and constraint lengths. The component with identical encoder is basically known as symmetric turbo codes, otherwise asymmetric turbo codes [1]. The parallel concatenated turbo codes can assume identical component code, as in the symmetric turbo codes, have either a good waterfall” BER performance or a good “error floor” BER performance, but
not both. The parallel concatenated codes which uses non-identical component codes known as asymmetric turbo codes. It has not only different constraint lengths but also different generator polynomials [8]. The resulting asymmetric turbo code has both good “waterfall” and “error-floor” BER performance [2][7]. The bit error rate (BER) performance curve of turbo codes can be divided into “waterfall” region and “error-floor” region. The “waterfall” region has a steep slope at lower SNR’s for a long block of information and “error-floor” region has a shallower slope at higher SNR’s caused by codeword of small weight [2].

In this paper, several new classes of asymmetric turbo codes are introduced which improves the performance compared to the original turbo codes (symmetric) over the entire range of signal to noise ratio. A practical setup with symmetric and asymmetric turbo codes is described and the performance results are discussed.

2. Asymmetric Turbo Code

2.1 Asymmetric Turbo Encoders

A turbo encoder is constructed by a parallel concatenation of two identical component codes, which are linked by a pseudo-random interleaver. Fig.1 shows a turbo encoder (rate 1/2) structure with two RSC encoders. Here trellis termination or truncation is performed on RSC encoders. Trellis termination is performed on the first RSC encoder, which returns its memory contents to zero state, while trellis truncation is performed on the second RSC encoder that leaves its memory states open.

Puncturing is a technique used to increase the code rate. A rate 1/3 encoder is converted to a rate 1/2 encoder by multiplexing the two coded streams. The multiplexer can choose the odd indexed outputs from the output of the upper RSC encoder and its even indexed outputs from the lower one.
Fig.2 shows the asymmetric turbo encoder with the code rate 1/2, which consists of (7,5)₁ encoder and (5,7)₂ encoder, where K is constraint lengths of turbo encoder and R is the code rate for the turbo codes.

### 2.2 Asymmetric Turbo Decoder

In a typical turbo decoding system (see Fig. 3), two decoders operate iteratively and pass their decisions to each other after each iteration [4].
Asymmetric Turbo Codes

There are many parameters which effect the performance of Asymmetric turbo codes as follows:

1. The number of decoding iterations
2. Code rate (puncturing)
3. Block length
4. Component codes
3.1 The effect of number of decoding iterations

The performance of an asymmetric turbo code using MAP algorithm with different iteration is shown in Fig 4. The generated polynomial used for the encoders are taken (7, 5) and (5, 7). It can be seen from above figure that, as the number of iterations increases BER performance increase. It observed that after 5 iterations there is a little improvement in performance approximately less than 0.1db so we can use only 8 iterations due to complexity reason.

3.2 The effect of different code rate

Half of the parity bits from each component encoders are punctured when we use the half rate code. But it is possible to avoid the puncturing and transmit all the parity bits through both the component encoders with one third code rate. The figure 5 shows the performance of BER taking different code rate.
3.3 The effect of block length

The BER performance is better as we increase the block length shown in fig 6. So, a large number of block lengths is an unacceptable in real time performance because of delay in transmission. In speech transmission we use 169 bit code while in video we use 1000 bit code. So as we increase the block length we don’t get the real time transmission however it would be useful in data or non-real time transmission.

3.4 The effect of component codes

Fig 7 shows the different generated polynomial which effects the performance by using MAP decoding technique. The generated polynomial used in this paper is for maximizing the minimum free distance of the component codes. The performance corresponding to the generator polynomial of (7, 5; 5, 7) and (17, 15; 17, 15) are shown and compared in the graph.
4. Proposed Asymmetric Turbo Codes

The proposed asymmetric turbo codes that uses parallel concatenated component encoders with mixed type of generator polynomials and different constraint lengths. Turbo codes with larger constraint length will achieve good performance and have better free distance but the computational complexity increases. It is necessary to decrease the constraint length of one of the component encoder in order to obtain good BER performance and reduce decoding delay.

Table 1 shows different types of asymmetric turbo codes with different constraint length and generator polynomials. Here P and NP describe primitive and prime polynomial for component encoders. G and K represent the feedback generator polynomial and the constraint length of each component codes, respectively. There are four types of turbo codes from each component codes: (NP, P) turbo codes, (P, NP) turbo codes, (P, P) turbo codes, (NP, NP) turbo codes. Here (P, P) turbo codes uses primitive polynomial for the feedback polynomial of all the component codes, and (NP, NP) turbo codes uses prime polynomial for the feedback polynomial of both the component codes but performance is similar to the conventional turbo codes. (P, NP) and (NP, P) turbo codes are a combination of primitive and prime (non-primitive) polynomial for the feedback polynomial of each component codes.

Table 1. Different types of asymmetric turbo codes with the different constraint lengths

<table>
<thead>
<tr>
<th>G</th>
<th>K</th>
<th>(P, NP) Turbo codes</th>
<th>(NP, P) Turbo codes</th>
<th>(NP, NP) Turbo codes</th>
<th>(P, P) Turbo codes</th>
</tr>
</thead>
<tbody>
<tr>
<td>K1=3, K2=3</td>
<td>G1=(7,5), G2=(5,5)</td>
<td>G1=(5,5), G2=(7,5)</td>
<td>G1=(5,5), G2=(5,5)</td>
<td>G1=(7,5), G2=(7,5)</td>
<td></td>
</tr>
<tr>
<td>K1=3, K2=5</td>
<td>G1=(7,5), G2=(37,21)</td>
<td>G1=(5,5), G2=(23,25)</td>
<td>G1=(5,5), G2=(37,21)</td>
<td>G1=(7,5), G2=(23,35)</td>
<td></td>
</tr>
<tr>
<td>K1=4, K2=3</td>
<td>G1=(15,17), G2=(5,5)</td>
<td>G1=(17,17), G2=(7,5)</td>
<td>G1=(17,17), G2=(5,5)</td>
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<tr>
<td>K1=4, K2=4</td>
<td>G1=(15,17), G2=(17,17)</td>
<td>G1=(17,17), G2=(15,17)</td>
<td>G1=(17,17), G2=(17,17)</td>
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<tr>
<td>K1=4, K2=5</td>
<td>G1=(15,17), G2=(37,21)</td>
<td>G1=(17,17), G2=(23,35)</td>
<td>G1=(17,17), G2=(37,21)</td>
<td>G1=(15,17), G2=(23,35)</td>
<td></td>
</tr>
<tr>
<td>K1=5, K2=3</td>
<td>G1=(23,35), G2=(5,5)</td>
<td>G1=(37,21), G2=(7,5)</td>
<td>G1=(37,21), G2=(5,5)</td>
<td>G1=(23,35), G2=(7,5)</td>
<td></td>
</tr>
<tr>
<td>K1=5, K2=4</td>
<td>G1=(23,35), G2=(17,17)</td>
<td>G1=(37,21), G2=(15,17)</td>
<td>G1=(37,21), G2=(17,17)</td>
<td>G1=(23,35), G2=(15,17)</td>
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<tr>
<td>K1=5, K2=5</td>
<td>G1=(23,35), G2=(37,21)</td>
<td>G1=(37,21), G2=(23,35)</td>
<td>G1=(37,21), G2=(23,21)</td>
<td>G1=(23,35), G2=(23,35)</td>
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</tr>
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</table>

If we use primitive polynomials as one of the feedback generator polynomials of the component encoders which shows degrading waterfall performance at lower SNR’s and lower error-floor at higher SNR’s. If we use non-primitive (prime) polynomials as one of the feedback generator polynomials which shows better waterfall performance at lower SNR’s. So, proposed asymmetric turbo code is a combination of primitive and prime generator polynomials. The component encodes with primitive generator polynomials may increase the free distance in order to reduce error-floor and...
component encoders with prime generator polynomials may optimize the distance spectrum to improve water-fall performance [2].

5. Simulation Results

Fig.8 shows the BER performance of asymmetric turbo codes with different combination of constraint length $K=3, 4$ for block size of 128 and 512. The simulation results of fig.6 (a) and 6(b) show that BER performance of symmetric turbo codes with $K_1=K_2=4$ is slightly superior to asymmetric turbo codes with $K_1=3, K_2=4$ or $K_1=4, K_2=3$. The performance of asymmetric turbo codes with $K_1=4, K_2=3$ is very close to symmetric turbo codes with constraint length $K_1=K_2=4$. By decreasing the
constraint length of second component encoder shows better BER performance when compared with asymmetric turbo codes with different constraint lengths.

![Graph showing BER performance comparison for different constraint lengths.](image)

**Figure 9**: BER performance of \((P, P)\) turbo codes with different constraint lengths 3, 4, 5 for block size of 128 and 512.

Fig. 9 shows the BER performance of both primitive type asymmetric turbo codes with different combinations of constraint length \(K=3, 4, 5\) for the block size of 128 and 512. The simulation results of fig. 7(a) and 7(b) show that performance of asymmetric turbo codes with \(K_1=3, K_2=5\) is inferior to turbo codes with \(K_1=5, K_2=3\). So, it is better to design asymmetric turbo codes with larger constraint length for the first component encoder. Performance of turbo codes with \(K_1=K_2=5\) is slightly superior to asymmetric turbo codes with \(K_1=4, K_2=5\) or \(K_1=5, K_2=4\). The proposed asymmetric turbo codes that use parallel concatenated component encoders with mixed type of generator polynomials and different constraint lengths. Turbo codes with larger constraint length will achieve good performance and have better free distance but the computational complexity increases. It is necessary to decrease the constraint length of one of the component encoder in order to obtain good BER performance and reduce decoding delay.
6. Conclusion
In this paper, two types of asymmetric turbo codes are constructed with different constraint lengths and mixed type of generator polynomials. The proposed scheme can improve the “waterfall” at the low SNR and “error-floor” at the high SNR while reducing the decoding computational complexity with the use of primitive and non-primitive polynomials alternatively. So, finally we concluded that the BER performance of asymmetric turbo codes have the advantage of the superior to conventional symmetric turbo codes. But the turbo codes with larger constraint length will increase delay and computational complexity. This asymmetric turbo codes widely used in mobile 3G communication systems.

7. References