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Performance of Turbo Codes using SOVA

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Abstract: Information Theory & Coding, Error Detection & Correction are the techniques that enable reliable transmission of information over unreliable communication channels. Error detection allows detection of such errors while error correction enables reconstruction of original data. The idea behind the error detection & correction is to add redundancy bits i.e. extra bits based on which data can be detected or corrected. The Turbo Codes resulted from the combination of convolutional codes, interleaving, soft-input soft-output decoding and concatenation. Turbo Codes are used to provide better Bit Error Rate performance over noisy channel as they come closest to Shannon's Capacity Limit. We have to examine the performance of the iterative soft output Viterbi algorithm (SOVA) for turbo codes on an additive white Gaussian noise channel and compare the performance to that of the other algorithm to achieve the best results.

Keywords: Turbo Code, AWGN, SOVA, OFDM.

I. INTRODUCTION

Now a day's Error detection and correction in system is very important because transmission of information over Unreliable channels have the unwanted noise contained in it. In coding first error detection techniques are applied to ensure noise is present or not. If errors are present then we have to apply error correction methods. Error detection & Correction schemes can be systematic or non systematic. In Systematic technique original information is transmitted along with check bits which are calculated by some algorithm for error detection & correction receiver applies the same decoding algorithm to the received data bits and compares its output with the received check bits; if the values do not match, an error has occurred at some point during the transmission.

In a system that uses a non-systematic code, the original message is transformed into an encoded message that has at least as many bits as the original message. Turbo Codes are also known as Parallel Concatenated codes and the decoding complexity is small for the dimension of code, whereas the code length possible is very long. The bounds of Shannon's Limit also become achievable for all practical purposes because the decoding complexity becomes small. SOVA (soft output Viterbi algorithm)is a modification of classical Viterbi algorithm, it helps to improve results. This paper explains configuration of turbo encoder and decoder and how this coding scheme provides better performance.

II. SYSTEM MODEL

This section explains the actual system model in detail. In figure 1, system model is shown. Input sequence is first passed through SOVA turbo encoder. Then after modulation it is transferred through a communication channel. At receiver side data is demodulated and passed through turbo decoder.

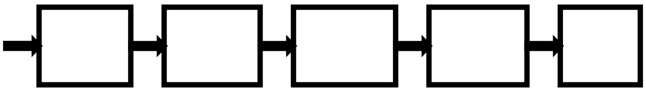

Fig. 1.System Model

A. CHANNEL

In telecommunications and computer networking, a communication channel or channel, refers either to a physical transmission medium such as a wire, or to a logical connection over a multiplexed medium such as a radio channel. A channel is used to convey an information signal, for example a digital bit stream, from one or several senders (or transmitters) to one or several receivers. A channel has a certain capacity for transmitting information, often measured by its bandwidth in Hz or its data rate in second. In wireless communications the channel is often modelled by a random attenuation (known as fading) of the transmitted signal, followed by additive noise. The attenuation term is a simplification of the underlying physical processes and captures the change in signal power over the course of the transmission. The noise in the model captures external interference and/or electronic noise in the receiver. If the attenuation term is complex it also describes the relative time a signal takes to get through the channel. The statistics of the random attenuation are decided by previous measurements or physical simulations.

B. AWGN

Additive white Gaussian noise (**AWGN**) is a basic noise model used in Information theory to mimic the effect of many random processes that occur in nature. The modifiers denote specific characteristics:

a) Additive because it is added to any noise that might be intrinsic to the information system.

b) White refers to the idea that it has uniform power across the frequency band for the information system. It is

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an analogy to the color white which has uniform emissions at all frequencies in the visible spectrum.

c) Gaussian because it has a normal distribution in the time domain with an average time domain value of zero.

A common channel model used is the Additive White Gaussian Noise, or AWGN, channel, which is a good model for many satellite and deep space communication links.

Wideband noise comes from many natural sources, such as the thermal vibrations of atoms in conductors (referred to as thermal noise or Johnson-Nyquist noise), shot noise, black body radiation from the earth and other warm objects, and from celestial sources such as the Sun. The central limit theorem of probability theory indicates that the summation of many random processes will tend to have distribution called Gaussian or Normal.

However, it produces simple and tractable mathematical models which are useful for gaining insight into the underlying behaviour of a system before these other phenomena are considered.

If a transmitted signal s(t) at the time t is sent over an AWGN channel the received signal r(t) is given by

$$r(t) = s(t) + n(t)$$

Where n (t) is Gaussian noise.

Since the signals sent over the channel are electric voltages the mean will be $\mu = \pm 1$.

This Gaussian noise is a random, normally distributed variable that can be expressed as the function

$$n(t) = \frac{1}{\sigma\sqrt{2\pi}} \exp^{-\frac{(t-\mu)^2}{2\sigma^2}} .$$

Sigma is the noise variable, and μ is the mean to the function of the normal distribution.

III. TURBO ENCODER

The basic idea of turbo codes is to use two convolutional codes in parallel with some kind of interleaving in between. Convolutional codes can be used to encode a continuous stream of data, but in this case we assume that data is configured in finite blocks - corresponding to the interleaver size. The frames can be terminated - i.e. the encoders are forced to a known state after the information block. The termination tail is then appended to the encoded information and used in the decoder. We can regard the turbo code as a large block code.

The performance depends on the weight distribution - not only the minimum distance but the number of words with low weight. Therefore, we want input patterns giving low weight words from the first encoder to be interleaved to patterns giving words with high weight for the second encoder. Convolutional codes have usually been encoded in their feed-forward form, like (G1, G2) = (1+D2, 1+D+D2). However, for these codes a single 1, i.e. the sequence ...0001000..., will give a codeword which is exactly the generator vectors and the weight of this codeword will in general be very low. It is clear that a single 1 will propagate through any interleaver as a single 1, so the conclusion is that if we use the codes in the feed-forward form in the turbo scheme the resulting code will have a large number of code words with very low weight.

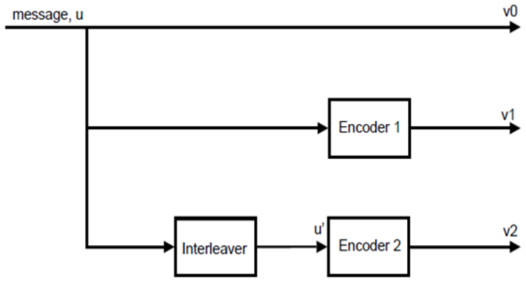

Fig. Turbo Encoder

A. RSC (Convolutional Encoder)

In telecommunication, a convolutional code is a type of error-correcting code that generates parity symbols via the sliding application of a boolean polynomial function to a data stream. The sliding application represents the 'convolution' of the encoder over the data, which gives rise to the term 'convolutional coding'. The sliding nature of the convolutional codes facilities trellis decoding using a time invariant trellis. Time invariant trellis decoding allows convolutional codes to be maximum likelihood soft decision decoded with reasonable complexity. The ability to perform economical maximum likelihood soft decision decoding is one of the major benefits of convolutional codes. This is in contrast to classic block codes which are generally represented by a time variant trellis and therefore are typically hard decision decoded. Convolutional codes are often characterized by the base code rate and the depth (or memory) of the encoder [n,k,K]. The base code rate is typically given as n/k, where n is the input data rate and k is the output symbol rate. The depth is often called the "constraint length" 'K', where the output is a function of the previous K-1 inputs. The depth may also be given as the number of memory elements 'v' in the polynomial or the maximum possible number of states of the encoder (typically 2^v).Convolutional codes are often described as continuous. However, it may also be said that convolutional codes have arbitrary block length, rather than that they are continuous, since most real world convolutional encoding is performed on blocks of data. Convolutionally encoded block codes typically employ termination.

B. Interleaving

Interleaving is merely just a rearranging of the data, or to be more precise, a rearranging of the order in which the data is read. For example, the four bits of data are arranged in a 2 x 2 matrix before the data is first encoded row wise, and then encoded column wise. This type of swapping is a simple form of interleaving and is called block interleaving.

C. Why interleave?

The main point of interleaving is to protect the data from burst errors. This can be explained by seeing the interleaving step as a temporal permutation of bits. If n errors occur on n consecutive bits in an uninterleaved code segment, then the errors will be spread over the entire block on the interleaved code segment. So what the interleaver really does is to increase the free distance to the concatenated code. The free distance in Turbo codes can be understood as the minimum Hamming distance of a code. Spectral thinning is a process that has been shown to reduce the number of low-weight code words and has therefore an impact on the minimum distance of the code.

D. Puncturing

Puncturing systematically removes some of the parity bits after encoding. This is, for example, applied to constituent codes. Both encoders might want to send the information. This repetition is inefficient so one encoder may puncture its information bits. The information bits in say, the second encoder are therefore ignored, and the rate of the code is increased.

E. Soft-Output Viterbi Algorithm (SOVA)

Soft Decision Viterbi Decoding, or SOVA for short, and is a decoding technique. There are two differences between the Viterbi algorithm and the SOVA. First, the path metrics are modified to use a priori information when deciding the path through the trellis that is most likely. Second, the soft output has reliability information about the decoded output. This reliability information is the posterior log-likelihood ratios. These kinds of decoders are also called Soft-In Soft-Out. As said earlier, every path through this trellis represents different codeword's. All these paths can be divided into states that are connected by an edge to one or two other states in the same path. Each of these states has a metric that denotes the"probability" of the surviving path going through their state. This metric M (sl) depends on the metric to the previous state M (s0 l−1) in the path and the metric to the edge, l (s0, s)5 between them, like in the original Viterbi algorithm. The metric is now defined by

$$M(s_l) \triangleq M(s'_{l-1}) + \ln(\gamma_l(s', s))$$

In a binary trellis all states will have two incoming edges. Since the trellis starts and ends in the all zero state the starting states will have one, or none incoming edges, because the rest of the states are unreachable and therefore ignored. Anyway, when two paths enter a state, their metrics are computed, and are then compared, and the largest metric M (sl) is selected, while the other M(ˆsl) is discarded. The difference between these two metrics is which the log-likelihood ratio of the selected metric is being the correct decision. It is shown in that the log-likelihood ratio of the information bit ul given the received bit rl can be approximated by

$$\Delta_l = M(s_l) - M(\hat{s}_l) \geq 0$$

$$L(u_l|r_l) \approx u_l \cdot \min_{i=l,\cdots,l+\delta} (\Delta_i)$$

Where _ is a number of states after l. The SOVA algorithm follows the same steps as the algorithm given in section 3.4.3. However, the soft input and output is computed by the equations above to find the most likely path. When the most likely path has been found the hard decisions are computed by using equation above. Showed that the SOVA algorithm is half as complex as the Max-Log-MAP algorithm.

IV. ITERATIVE DECODING

In a typical communication receiver demodulator is often designed to produce the soft decision which is then transferred to decoder. The improvement in error performance of system utilizing such soft decision is typically approximated as 2 dB, as compared to hard decisions in AWGN. Such a decoder could be called soft input/ hard output decoder, because the final decoding process out of the order must terminate in bits .With turbo Codes Where two or more component codes are used and decoding involves feedings output from one decoder to inputs of other decoders to input of others decoders in an iterative fashion a hard output decoder would not be suitable.

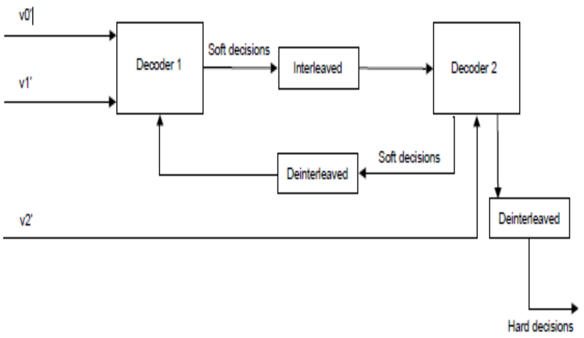

Fig.2 Turbo Decoder

That is because a hard decision into a decoder degrades system performance. Thus what is needed for the decoding of Turbo Codes is a soft input/soft output decoder.
At first iteration the probability of error rate is much more as shown in Red line, secondly the violet line shows the next iterations it shows that some better result is achieved i.e. the BER is reduced ,third iteration shows that Green line the error rate going to be low as compared to previous iterations. Fourth iteration denotes that the error rate is negligible i.e. is very less.

The Turbo Code denotes that as numbers of iterations are increased the performance also increased.

Performance Simulation of Decoder

The Graph show the comparison of bits transmitted without coding and same bits transmitted with Turbo coding. Graph for frame size of 400 bit, with SOVA decoding algorithm and a rate of ½ without puncturing. This shows that Turbo Codes show a much better BER for wireless transmission. The above graph shows that Bit error rate vs number of frames with time. The larger the frame size, the bigger the S-window. Therefore, it will produce larger distance by using an interleaver. The correlation between the two adjacent bits will become smaller. Hence, the decoder gives better performance.

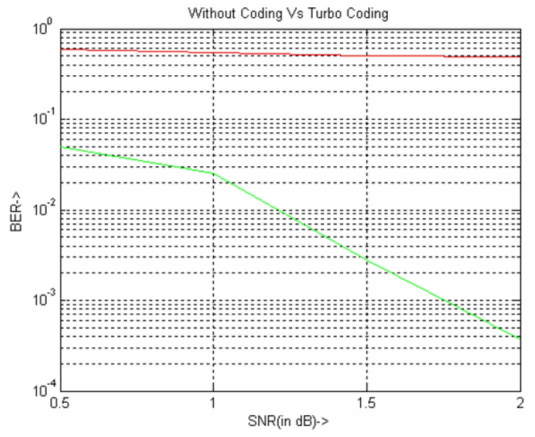

Fig.3 BER vs SNR

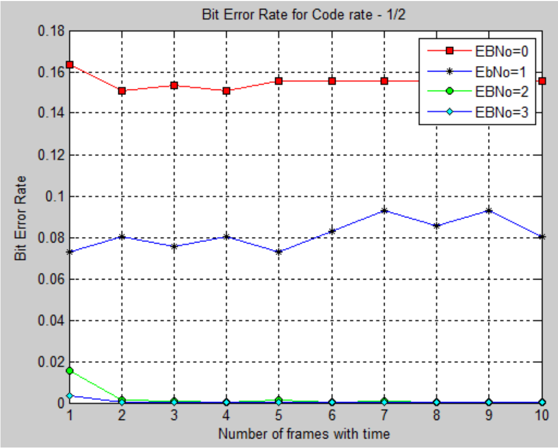

Fig.4 Bit error rate for code rate

The simulation results verified this conclusion. However, since Turbo code is a block code, it causes a time delay before getting the complete decoding output. Increasing the frame size also increases the delay time.

Following graph shows the BER's of Turbo code under fading channel with the code rate=1/2, iteration=4, frame size L =50,100, & 400 bits. From the figure, we can see that the Turbo code with lager frame size has better performance.

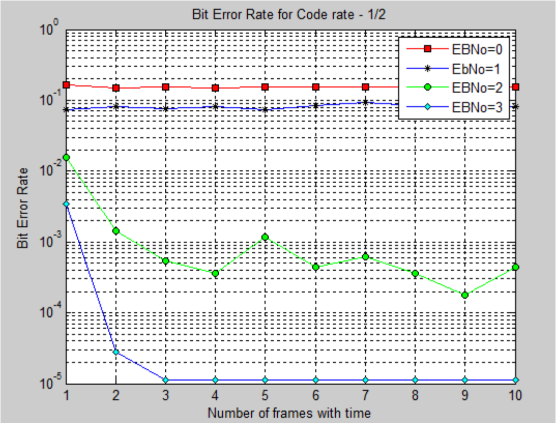

Fig.5 BER vs Number of Frames

At first iteration the probability of error rate is much more as shown in Red line, secondly the violet line shows the next iterations it shows that some better result is achieved i.e the BER is reduced ,third iteration shows that Green line the error rate going to be low as compared to previous iterations. Fourth iteration denotes that the error rate is negligible i.e is very less. The Turbo Code denotes that as numbers of iterations are increased the performance also increased.

VI. CONCLUSION

Digital modulation is more reliable than analogue modulation in many terms. The use of Soft output mechanism is more convient. It gives the results more accurate. By using the MATLAB software coding can be done. Various algorithms are there but Soft output Viterbi algorithm archives the result near about to Shannon limit. It shows the lowest bit error rate when the number of iterations are increased. Delay time can be reduced; performance is increased in long frames. It is so efficient signal to noise ratio between 1dB to 2.5dB if the data rate is ½.

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