TSG-RAN Working Group1 meeting #2
TSGR1#2(99)037
Yokohama 22-25, February 1999

Agenda Item:

Source: Lucent Technologies

Title: Comparison of different code-embedded interleavers

Document for: Discussion

Introduction

In this document, we compare four different interleavers chosen after an extensive search within the classes of interleavers left for UMTS applications after the ETSI Meeting # 10 in Espoo, Finland.

The interleavers belong to the classes proposed by NTT-DoCoMo, Hughes Network Systems (HNS), and Nortel, to which we added an S-random interleaver, which, although being outside the ETSI choice, had been shown to be the best in a previous document [1], and is thus considered here only as a milestone to compare the others. The fourth class of interleavers chosen by ETSI had been proposed by Canon, and is not considered here as it can be considered as a particular case of the Nortel interleaver.

The interleavers will be compared, for the sake of simplicity and computer time, on the additive white Gaussian noise channel, using a serially concatenated convolutional code (SCCC) with rate 1/3, based on an outer 2/3 code and an inner ½ code, both with 4 states. The information block sizes are N=320, N=640 which correspond to an interleaver size of 483 (320x3/2+3) including termination of the outer trellis.

The description of the NTT-DoCoMo, HNS and Nortel interleavers can be found in the Documents [2-4]. We acknowledge the fact that the NTT-DoCoMo interleavers have been kindly provided by the experts of the proposing company. The S-random interleaver has been described in a previous document [1].

The search for “good” interleavers

The interleaver affects the performance of a serial (or parallel) concatenated code in two distinct ways:

- It influences the distance spectrum of the code, thus yielding different maximum-likelihood performance. This aspect is crucial to enhance, or reduce, the so-called error floor of the code. In this respect, the interleaver choice is more important for parallel than for serial concatenations, since the error floor is more pronounced.
- It modifies the correlation between the extrinsic information sequence entering the SISO decoders, thus affecting the rate of convergence of the suboptimum, iterative decoding algorithm.

In a search for good interleavers, there are no easy ways to compute the correlation between the extrinsic informations, other than undertaking extensive (and time consuming) simulations. As a consequence, using it as a choice criterion, only a few interleavers within a class could be tested.

On the other hand, we have developed two fast and efficient algorithms to estimate the first terms of the distance spectrum, so that we decided to use them for testing a large number of candidate interleavers within a class. The procedure we have adopted to choose candidate interleavers is as follows:

- First, we generate randomly the set of parameters that characterises one particular interleaver in a class, by using the degrees of freedom of that class (as an example, Nortel interleavers depend on eight parameters that can be chosen independently).
- Then, setting a goal in terms of free distance, we perform a fast estimate of the code free distance using a subset of information words that most likely will generate low-weight code words, and retain those interleavers for which the lowest code weight is not less than the free distance goal.
- Finally, for the best interleavers survived to the previous step, we compute exactly the free distance using an algorithm that tries all information words with weight less than the estimated free distance, thus making an exhaustive verification.

In particular, using the degree of freedom offered by the Nortel and HNS interleavers, we have generated and tested (in terms of free distance) 10,000 Nortel interleavers and 100,000 HNS interleavers, choosing the best interleaver in each class. As for NTT-DoCoMo MIL interleaver class, there seem not to be degrees of freedom in the class, apart from the number of states of the constituent codes, so that we asked NTT-DoCoMo to kindly generate and provide the interleaver to be used.

N=320

In the next Table, we report the three parameters characterising the chosen interleavers for interleaver size equal to 483, corresponding to information block size N=320, i.e., the free distance, the number of near neighbours at free distance, and the Hamming weight of the information sequences generating the free-distance error events.

-

Code-embedded Interleaver with size 483	**Free distance / # of paths at free distance /overall input information weight**
S-random (Lucent)	28 / 1 / 5
HNS	29 < d <= 32
NTT DoCoMo	25 / 1 / 3
Nortel	29/1

Performance over AWGN channel

As a second way of comparison, we have simulated the performance of the four SCCCs employing the same 4-state codes and the different interleavers over the additive Gaussian noise channel. In Figure 1 we report the obtained simulation results in terms of both bit and frame error probabilities using 10 iterations of the decoding algorithm. In order to give evidence to the error floor phenomenon, we have also used 100 iterations of the decoding algorithm, and the results are reported in Figure 2.

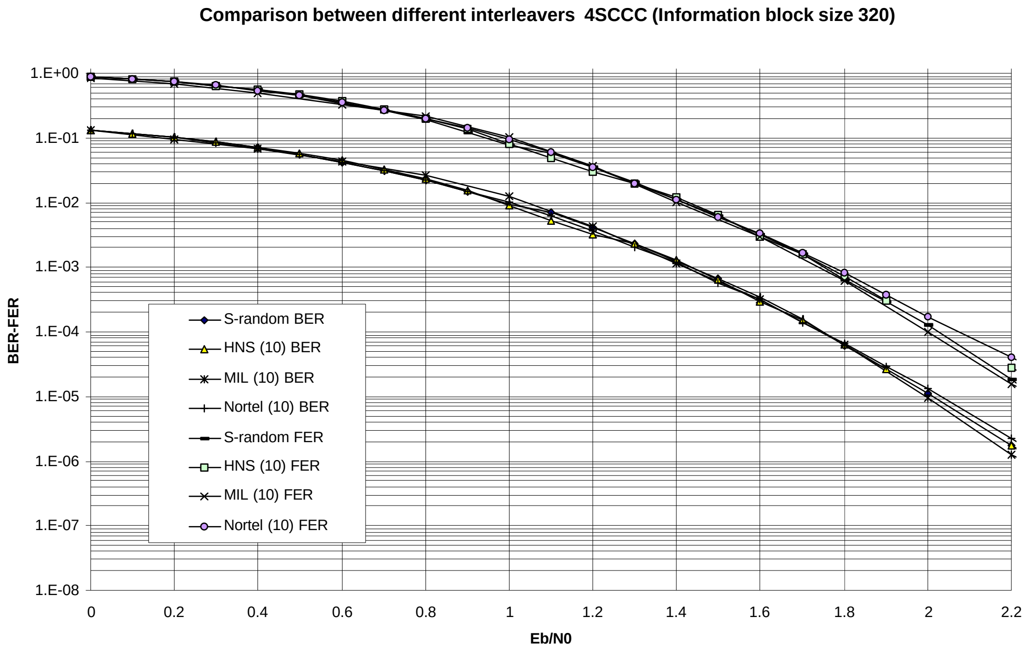

Figure 1: Comparison of different code-embedded interleavers on SCCC with N=320. 10 iterations.

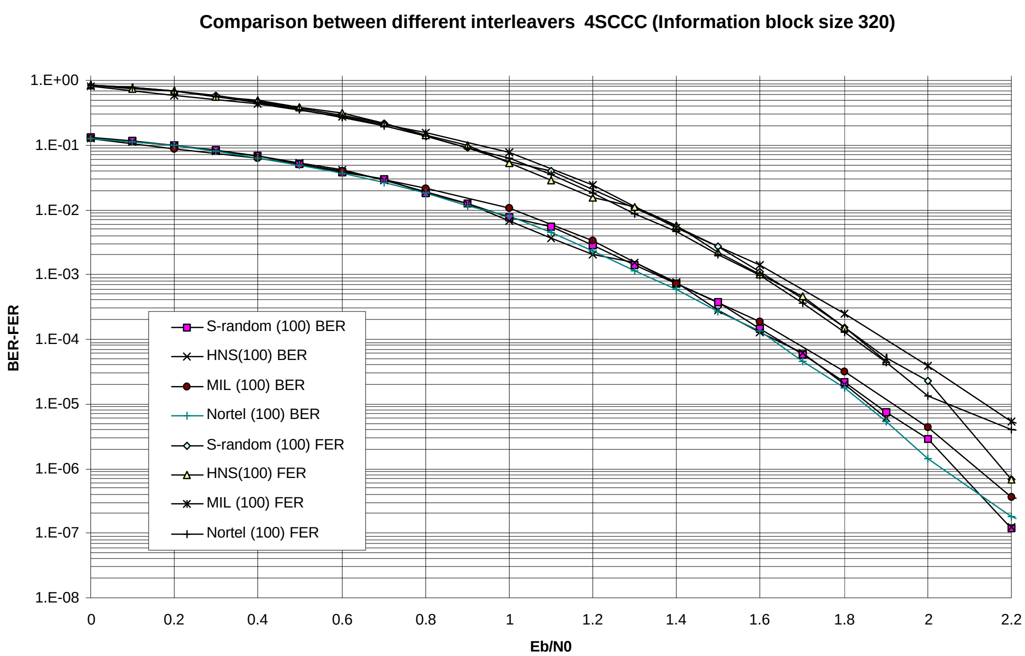

Figure 2: Comparison of different code-embedded interleavers on SCCC with N=320. 100 iterations.

It is interesting to note that the hierarchy of the interleavers changes when passing from 10 to 100 iterations, because the performance with 100 iterations are mainly influenced by the free distance of the code. The best interleaver at 10 iterations is the MIL interleaver, whereas at 100 iterations the HNS and S-random interleavers are better. It must be said, on the other hand, that the differences at 10 iterations are marginal.

N=640

We have also performed a search for HNS and Nortel interleavers for the information block size N=640, corresponding to interleaver size 963. In the next Table, we report the three parameters characterising the chosen interleavers, i.e., the free distance, the number of near neighbours at free distance, and the Hamming weight of the information sequences generating the free-distance error events.

For the S-random interleaver, we had no time to evaluate the free distance.

Code-embedded Interleaver With size 963	**Free distance / # of paths at free distance / overall input information weight**
S-random (Lucent)	--
HNS	29 < d <= 36
NTT DoCoMo	29/2/18
Nortel	25/10

Performance over AWGN channel

As a second way of comparison, we have simulated the performance of the four SCCCs employing the same 4-state codes and the different interleavers over the additive Gaussian noise channel. In Figure 3 we report the obtained simulation results in terms of both bit and frame error probabilities using 10 iterations of the decoding algorithm. In order to give evidence to the error floor phenomenon, we have also used 100 iterations of the decoding algorithm, and the results are reported in Figure 4.

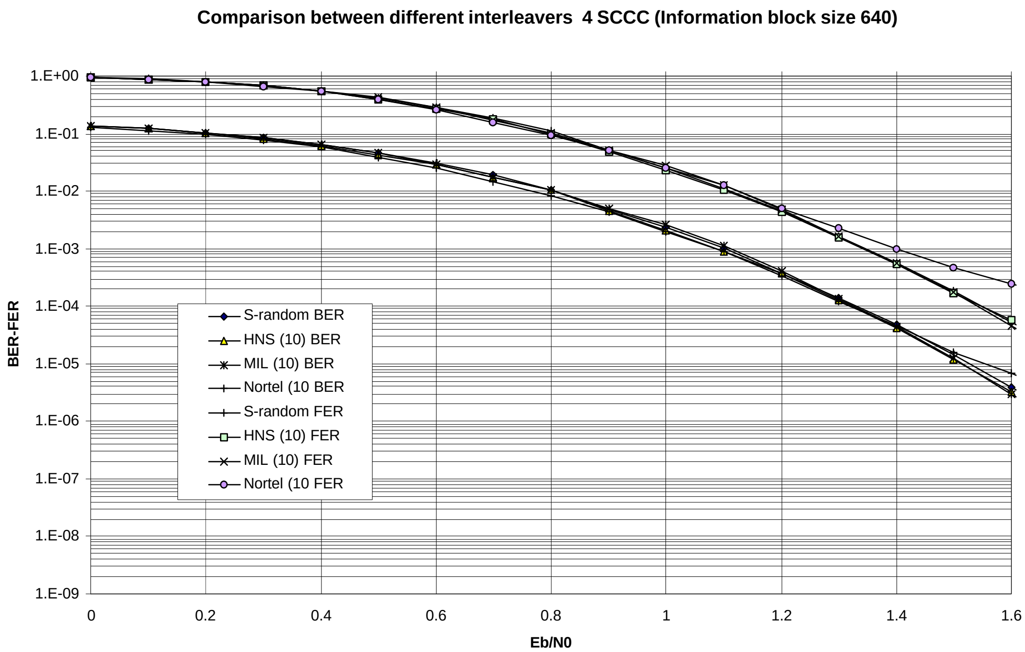

Figure 3: Comparison of different code-embedded interleavers on SCCC with N=640. 10 iterations.

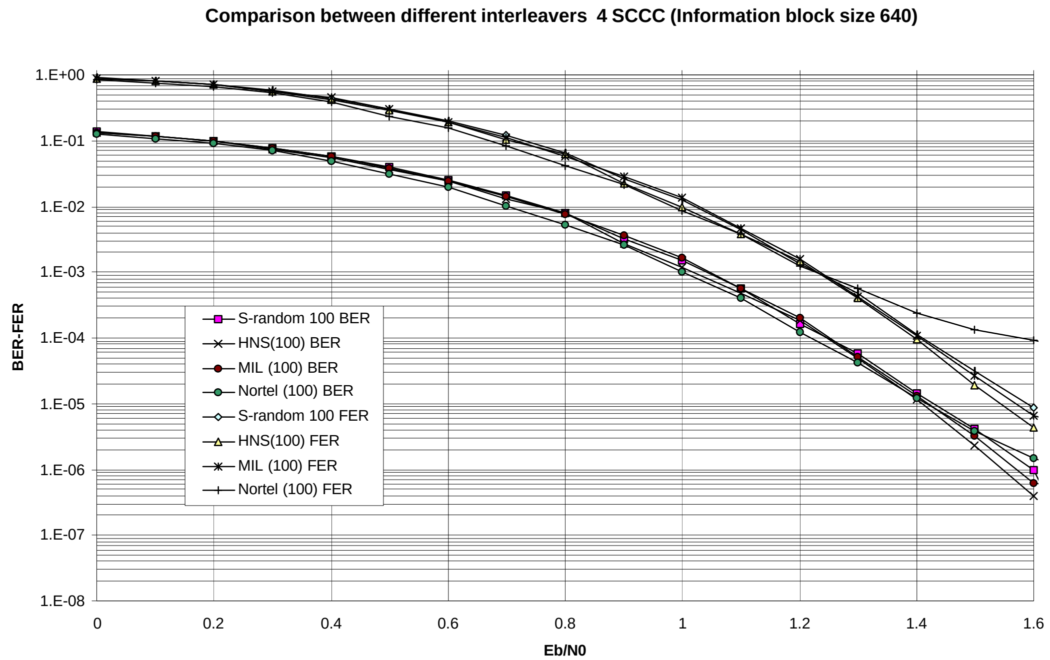

Figure 4: Comparison of different code-embedded interleavers on SCCC with N=640. 100 iterations.

Also in this case, we notice that the hierarchy of the interleavers changes when passing from 10 to 100 iterations, because the performance with 100 iterations are mainly influenced by the free distance of the code. The best interleaver at 10 iterations is the MIL interleaver, whereas at 100 iterations the HNS interleaver is better. The Nortel interleaver is not very good, and, for it in this case, the search should be extended.

Conclusions

- We have implemented an efficient search algorithm to test and choose good interleavers by generating large numbers of them in the interleaver classes that possess some degree of freedom to be exploited. We can also evaluate the free distances of the obtained codes.
- Using the search algorithm, we have found good interleavers for information block sizes of 320 and 640, and simulate them using a 4-state SCCC. The very large number of iterations (up to 100) makes it possible to set evidence to the error floor phenomenon.
- The simulation results for 10 and 100 iterations clearly show that the code behaviour, as far as the code-embedded interleavers are concerned, is influenced by the code free distance and also by other interleaver properties related to the iterative decoding algorithm. When the number of iterations increases, the free distance of the code becomes the dominant parameter.

References

[1] Lucent Tdoc SMG2 UMTS-L1 2x99-034.

[2] NTT-DoCoMo UMTS Document dated 23 December 1998.

[3] Hughes Network Systems Tdoc SMG2 UMTS-L1 765/98.

[4] Nortel Tdoc SMG2 UMTS-L1 XXX/98.