Technical Specification Group Services and System Aspects **TSGS#27 (05)0164**

Meeting #27, Tokyo, Japan, 14-17 March 2005

Source: **Siemens**

Title: **Efficient FEC code for reliable MBMS user services**

Agenda Item: **7.4.2 or 7.4.3 (MBMS FEC)**

Document for: **Discussion and approval**

Rationale

A variety of FEC (Forward Error Correction) codes for reliable MBMS download and streaming services have been proposed and carefully investigated in SA4 during the last year. There were several variants of Reed-Solomon codes (one-dimensional codes with and without interleaving, two-dimensional codes with and without sophisticated puncturing schemes), LDPC copper codes, and Raptor codes.

Various scenarios have been considered for the investigation including streaming services over GERAN and RAN with different data rates and PDU loss conditions as well as reliable file download of different sizes under different loss conditions. In almost all cases Raptor codes showed a significantly better erasure correction capability compared to the other proposed FEC codes. As a consequence, the overhead to be spent for error correction is lower when Raptor codes are used. This means a substantial reduction of transmission cost.
Only for downloads of small files (up to about 100 kB) a particular type of Reed-Solomon codes leads to a slightly smaller overhead. In this case a one-dimensional Reed-Solomon code on a finite field not larger than GF(256) performs like an ideal FEC code. On the other hand the saving in FEC overhead is in the range of 1 to 2% which is negligible due to the small file sizes. For larger files, i.e. for 500 kB and more, Raptor codes reduce the required overhead (and transmission cost) by up to 6 to 8%.

Besides higher efficiency with respect to erasure correction capabilities, the decoding of Raptor codes requires less computational effort compared to Reed-Solomon codes. Moreover, the complexity scales linearly with the file size while Reed-Solomon codes scale quadratically.

In the Annex simulation results are presented for FEC protection of MBMS file download over a UTRAN 64 kbps bearer. These results clearly confirm the superiority of Raptor codes over Reed-Solomon codes. The results also show that without any FEC protection a tremendous amount of overhead has to be spent for individual retransmission of lost packets by means of a point-to-point repair service.

Proposal

SA4 carefully investigated the performance of various FEC codes and decided to include Forward Error Correction (FEC) as a mechanism for improving the error resilience of a data stream. According to the superior performance we propose to use Raptor FEC for the recovery of lost data packets in MBMS download and streaming services.

We propose to approve the selection of the FEC codes now at SA#27. Based on this decision SA4 should be asked to present the technical specification at next SA plenary for approval.

Annex: Simulation results

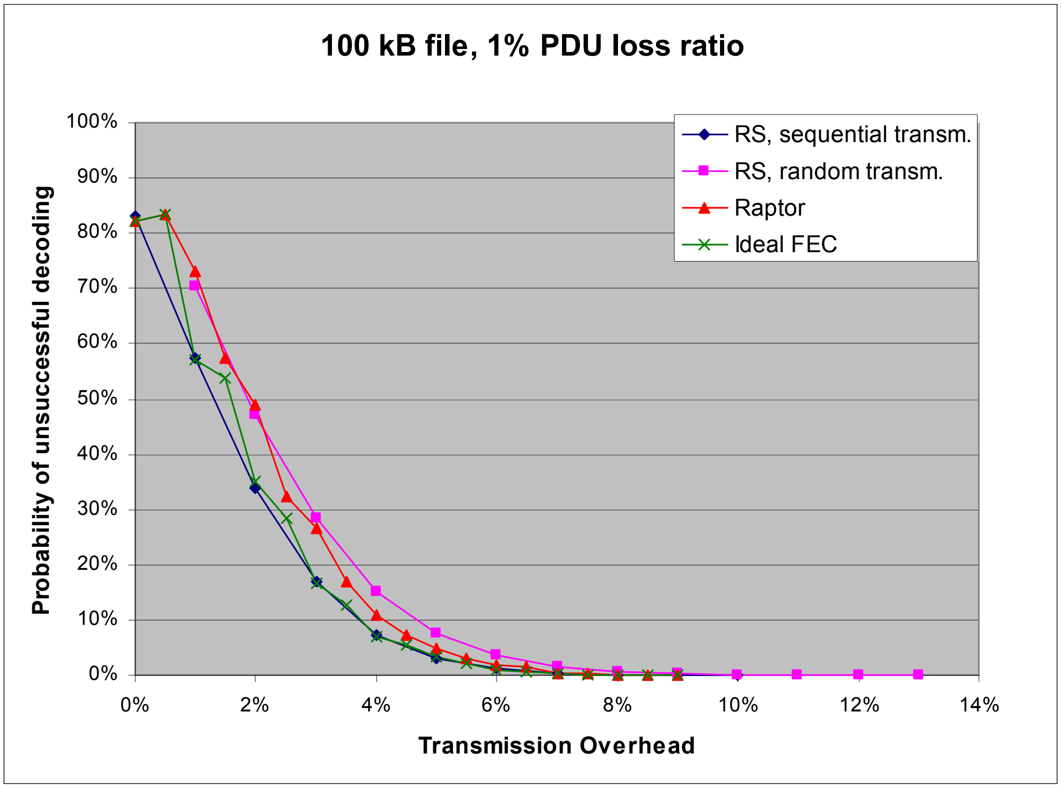
The following figures show the simulation results of two dimensional Reed-Solomon Codes and Raptor Codes for MBMS file download services over a 64 kbps UTRAN bearer with TTI = 80ms. Also included are the results of an "ideal code", which indicates the information theoretical limit. The following file sizes, packet size, and PDU loss ratios have been used:

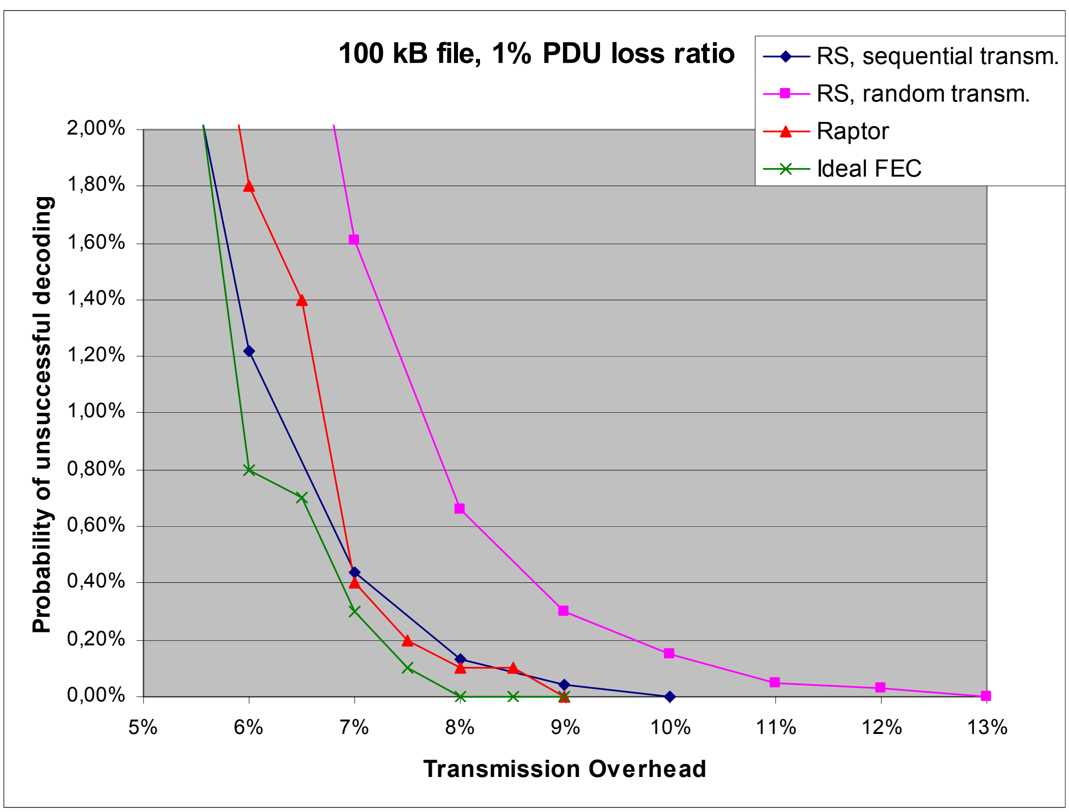
- File sizes: 100 kB, 500 kB, and 3 MB
- Packet size: 556 B including 44 B for FLUTE protocol header
- PDU loss ratios: 1%, 5%, 10% random
- PDU size: 640 B

For the simulation a seamless mapping of the 556 B SDUs onto the PDUs is assumed. Correspondingly, a loss of a single PDU causes loss of two or three consecutive SDUs.

Each simulation is at least 1000-times repeated with different PDU loss patterns of the same loss ratio. As a result, the probability of successful decoding (perfect reconstruction) or, alternatively, the probability of decoding failure can be plotted against the transmission overhead required for the error correcting codes. In the diagrams, the latter has been used in order to easier show in more detail the important part where the probability of decoding failure is very low. On the following pages there are two diagrams, the upper one shows the full range from 0 to 100% and the lower one shows the details from 0 to 2% block decoding failure probability.

The diagrams contain two curves for Reed-Solomon-Codes besides the curves for an ideal code and the Raptor code. It has been realized, that, according to the consecutive loss of SDU frames, a random transmission of source and repair packets improves the error correcting performance of RS codes in case of small loss ratios for larger files. Nevertheless, they still do not outperform Raptor codes where no interleaving is required.


100 kB file, 1% PDU loss ratio
RS, sequential transm.
RS, random transm.
Raptor
Ideal FEC
Probability of unsuccessful decoding
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0%
2%
4%
6%
8%
10%
12%
14%
Transmission Overhead


100 kB file, 1% PDU loss ratio
RS, sequential transm.
RS, random transm.
Raptor
Ideal FEC
Probability of unsuccessful decoding
2,00%
1,80%
1,60%
1,40%
1,20%
1,00%
0,80%
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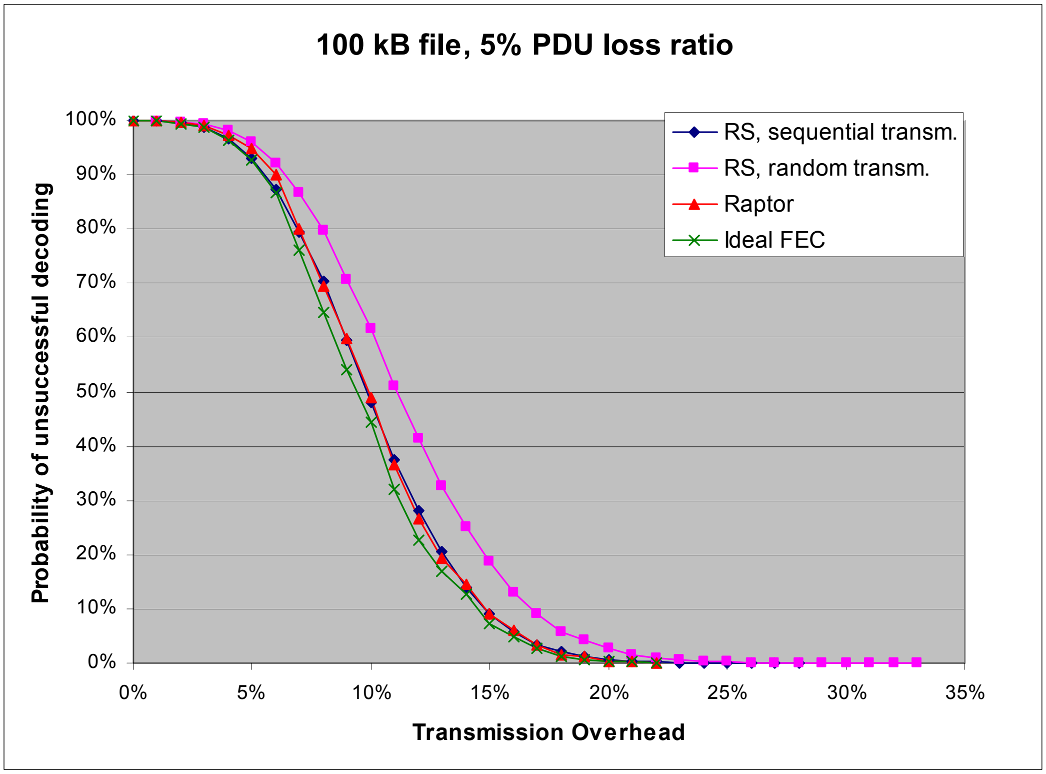
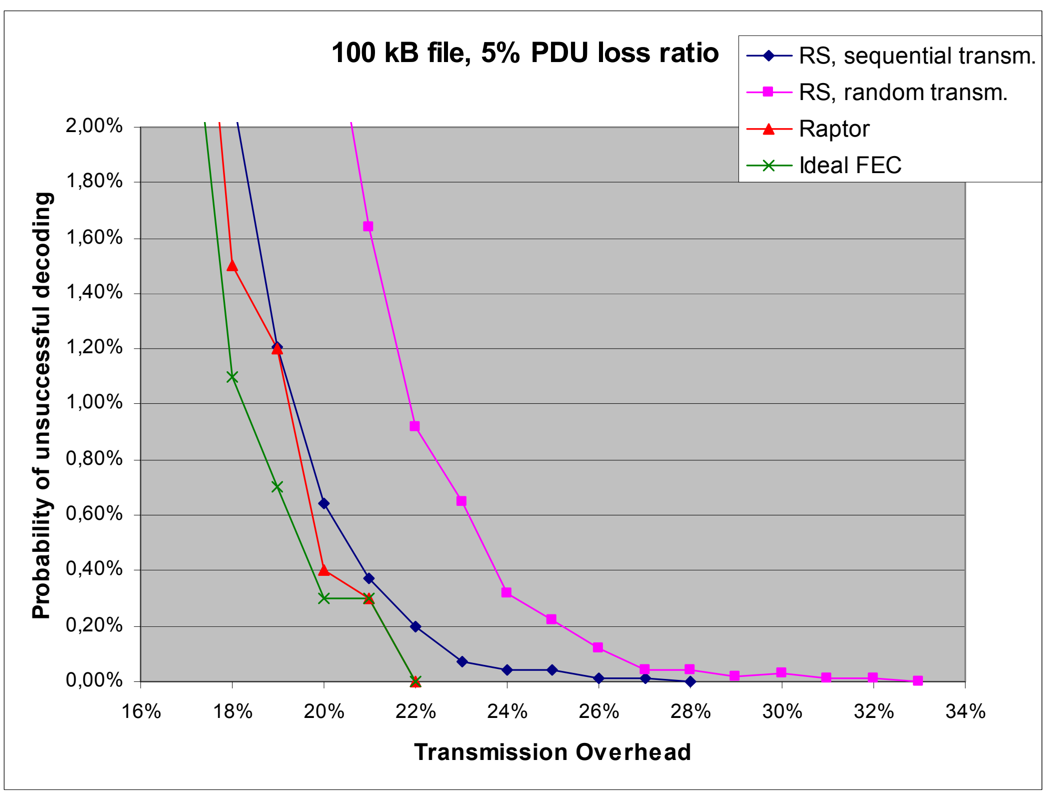
Transmission Overhead


100 kB file, 5% PDU loss ratio
RS, sequential transm.
RS, random transm.
Raptor
Ideal FEC
Probability of unsuccessful decoding
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0%
5%
10%
15%
20%
25%
30%
35%
Transmission Overhead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RS, random transm.
Raptor
Ideal FEC
Probability of unsuccessful decoding
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1,80%
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1,40%
1,20%
1,00%
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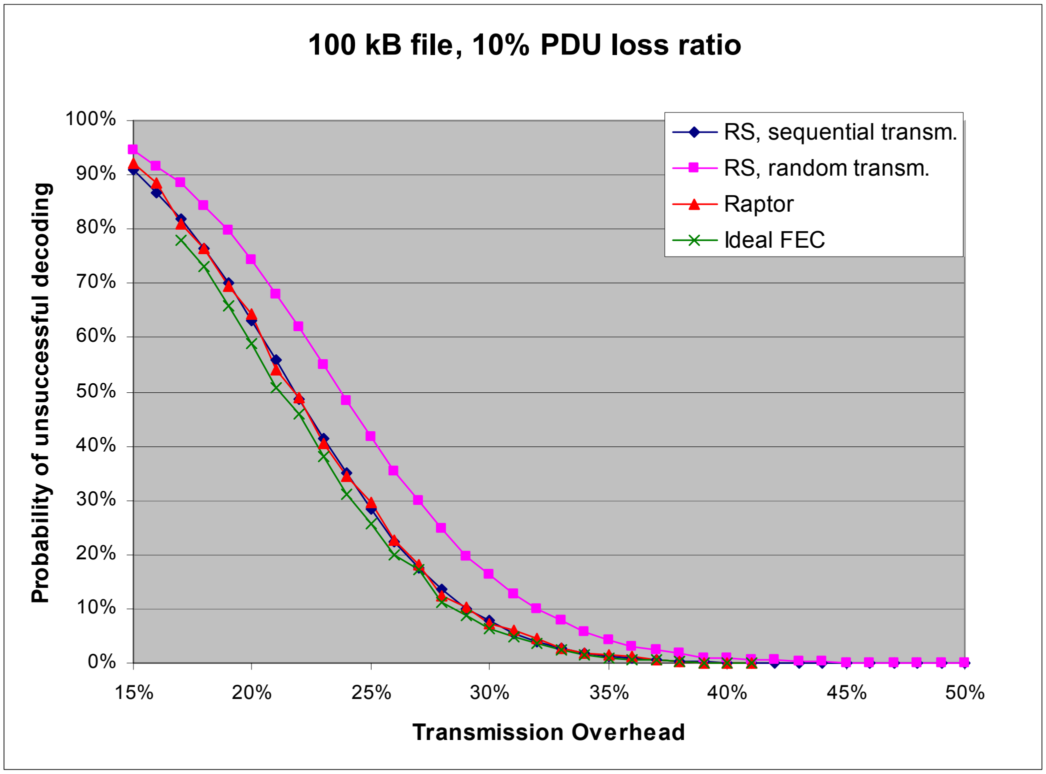
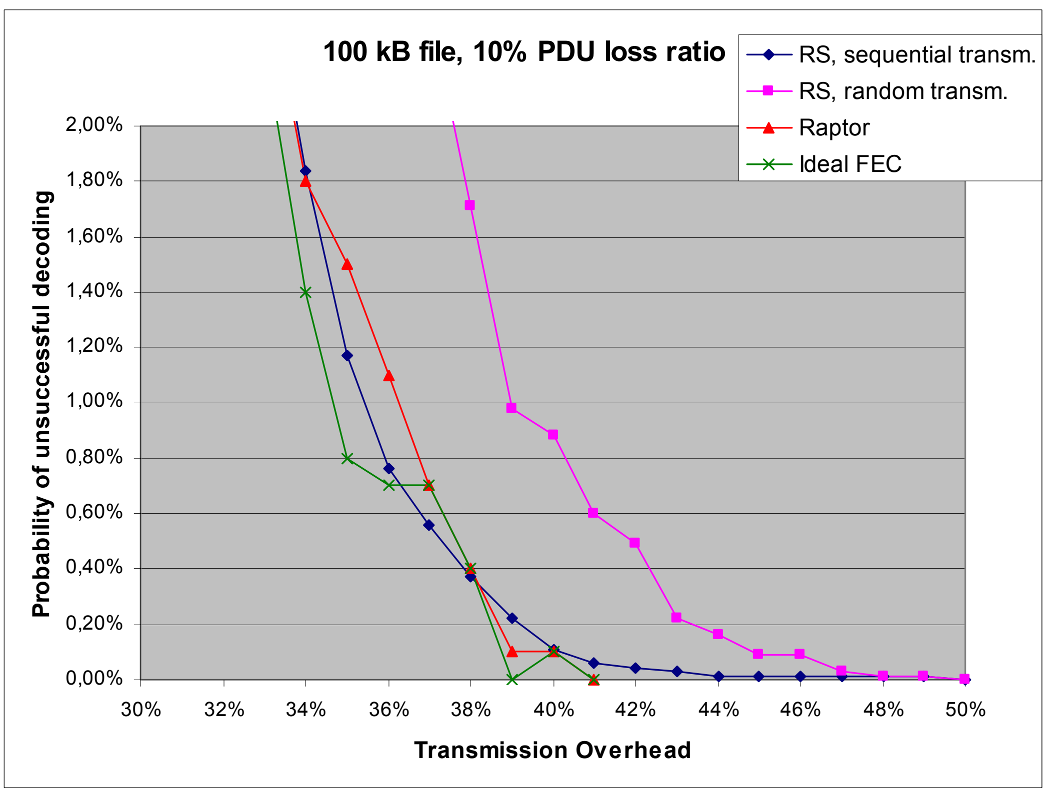
Transmission Overhead


100 kB file, 10% PDU loss ratio
RS, sequential transm.
RS, random transm.
Raptor
Ideal FEC
Probability of unsuccessful decoding
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
15%
20%
25%
30%
35%
40%
45%
50%
Transmission Overhead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0,40%
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0,00%
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46%
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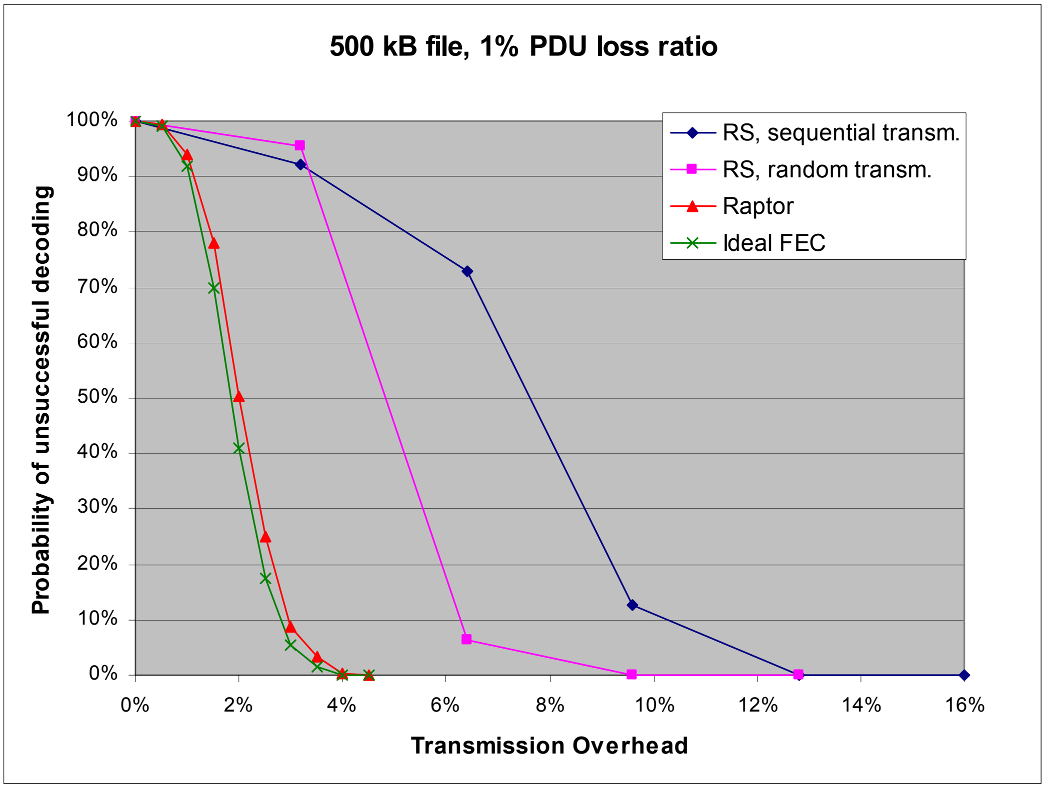
50%
Transmission Overhead


500 kB file, 1% PDU loss ratio
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RS, random transm.
Raptor
Ideal FEC
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90%
80%
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60%
50%
40%
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20%
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4%
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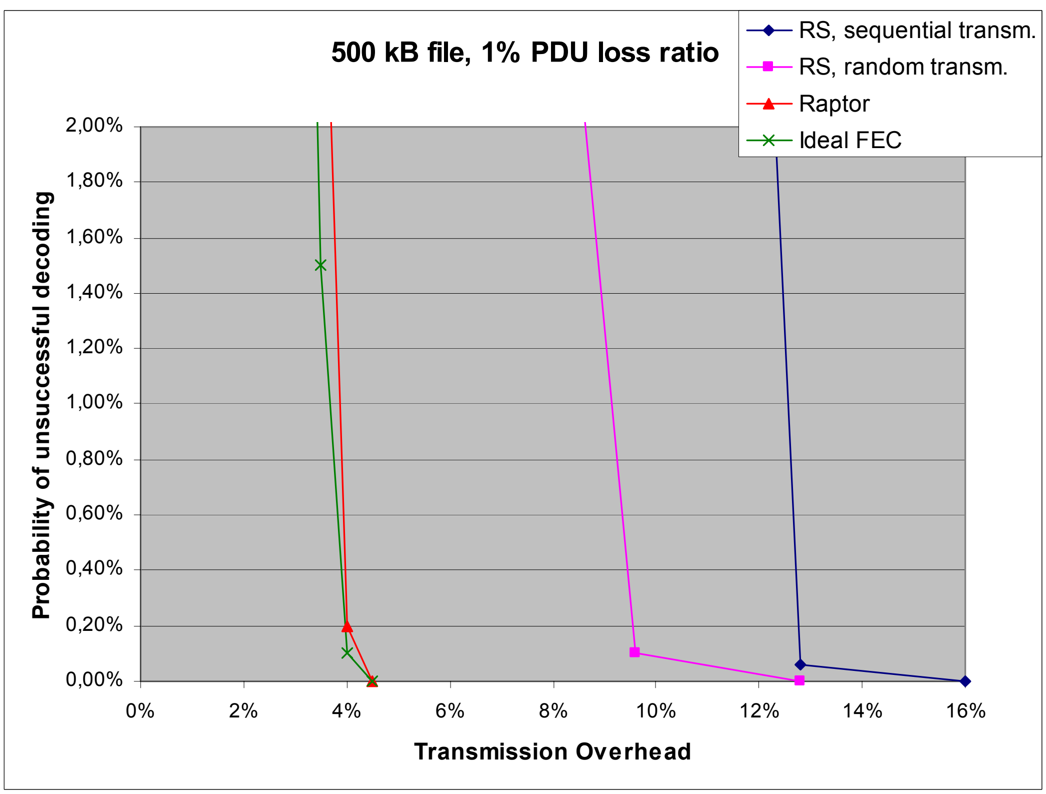
16%
Transmission Overhead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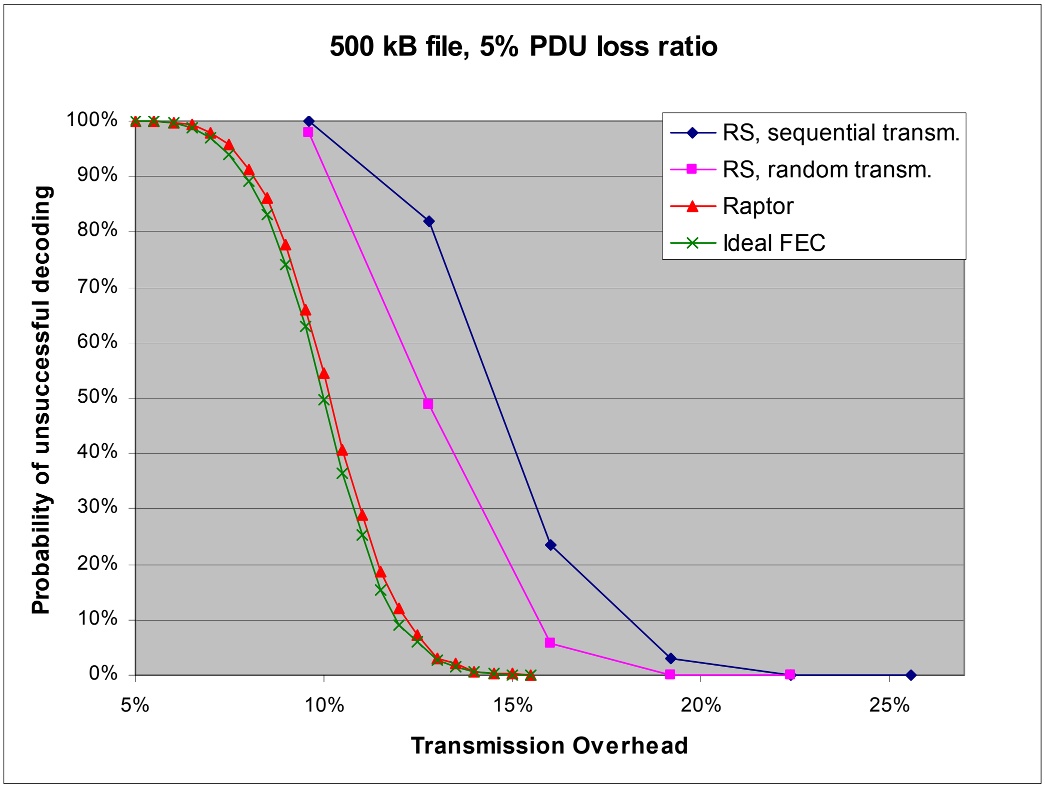
Transmission Overhead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10%
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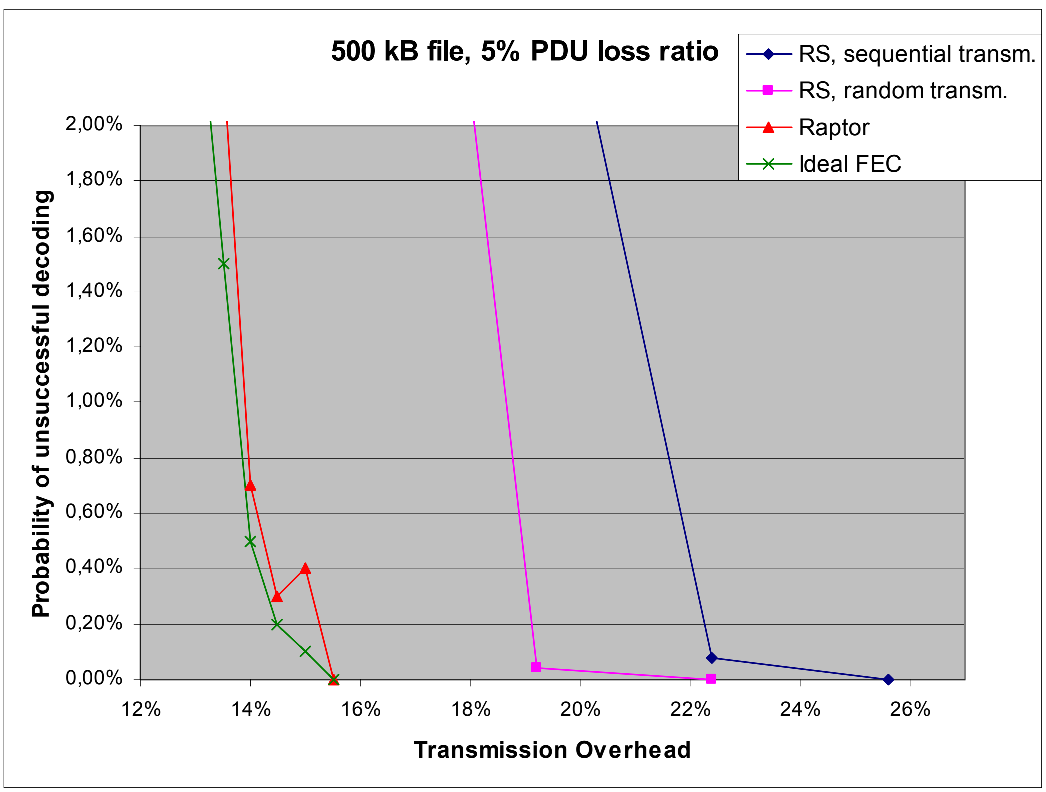
25%
Transmission Overhead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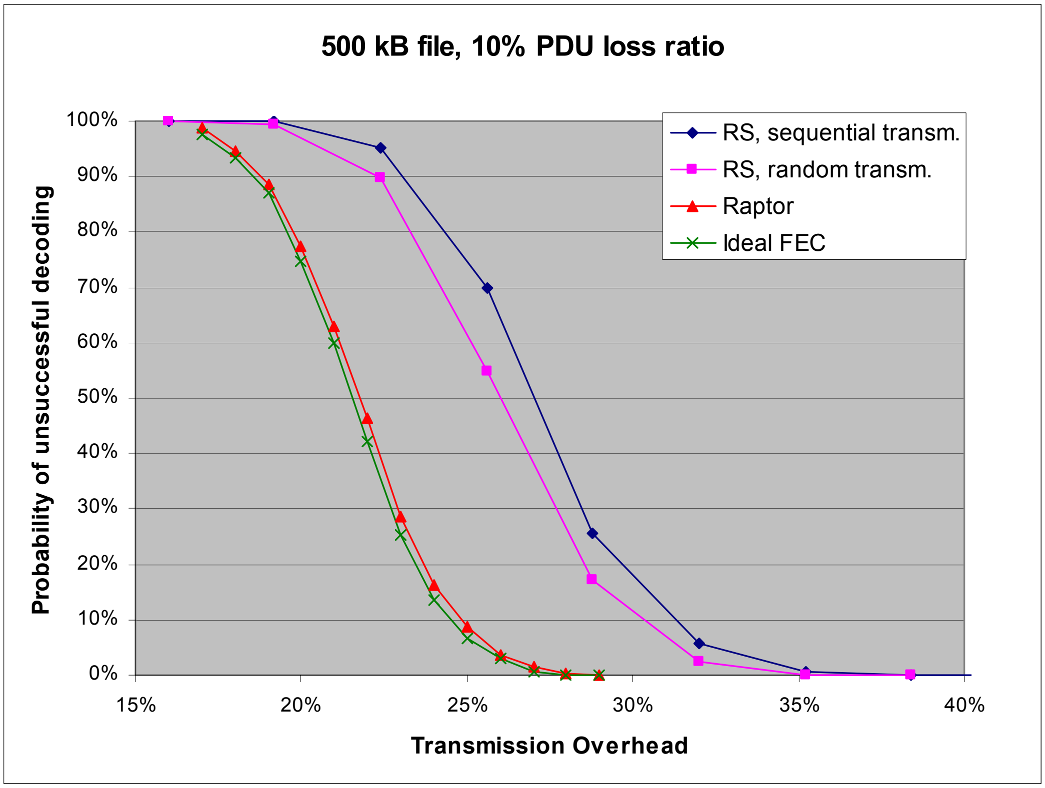
26%
Transmission Overhead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30%
20%
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0%
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20%
25%
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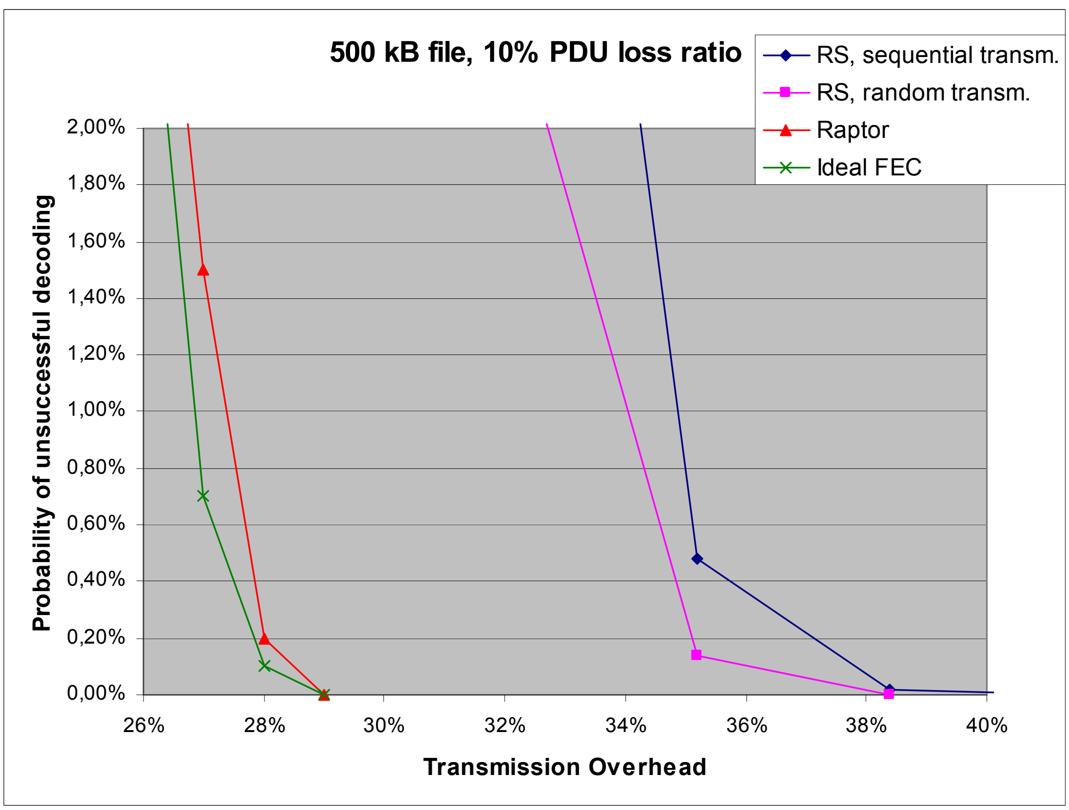
35%
40%
Transmission Overhead


500 kB file, 10% PDU loss ratio
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Raptor
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0,40%
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36%
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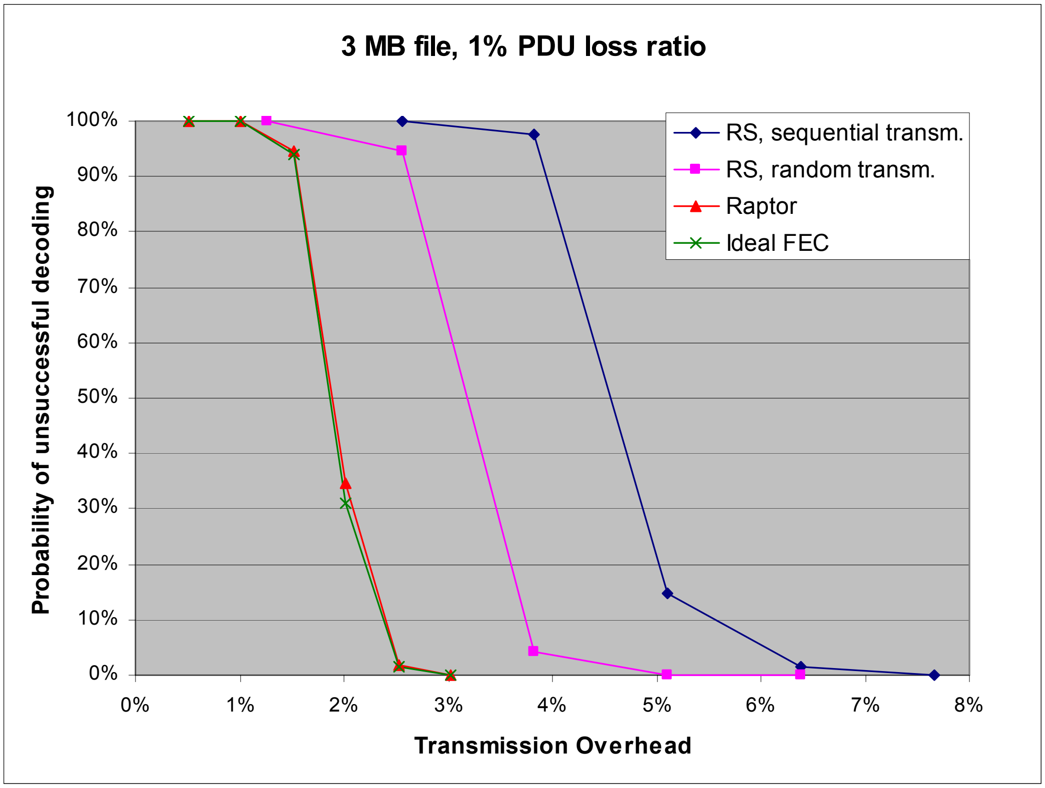
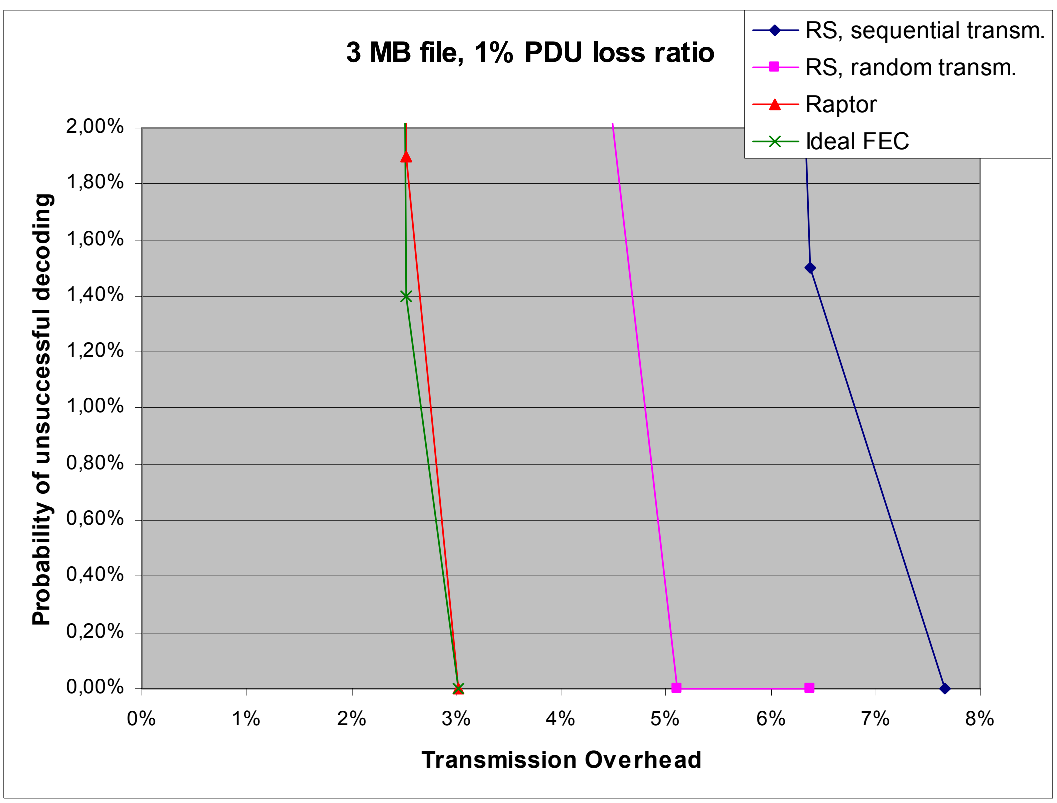
Transmission Overhead


3 MB file, 1% PDU loss ratio
Probability of unsuccessful decoding
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0%
1%
2%
3%
4%
5%
6%
7%
8%
Transmission Overhead
RS, sequential transm.
RS, random transm.
Raptor
Ideal FEC


3 MB file, 1% PDU loss ratio
Probability of unsuccessful decoding
2,00%
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1,40%
1,20%
1,00%
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7%
8%
Transmission Overhead
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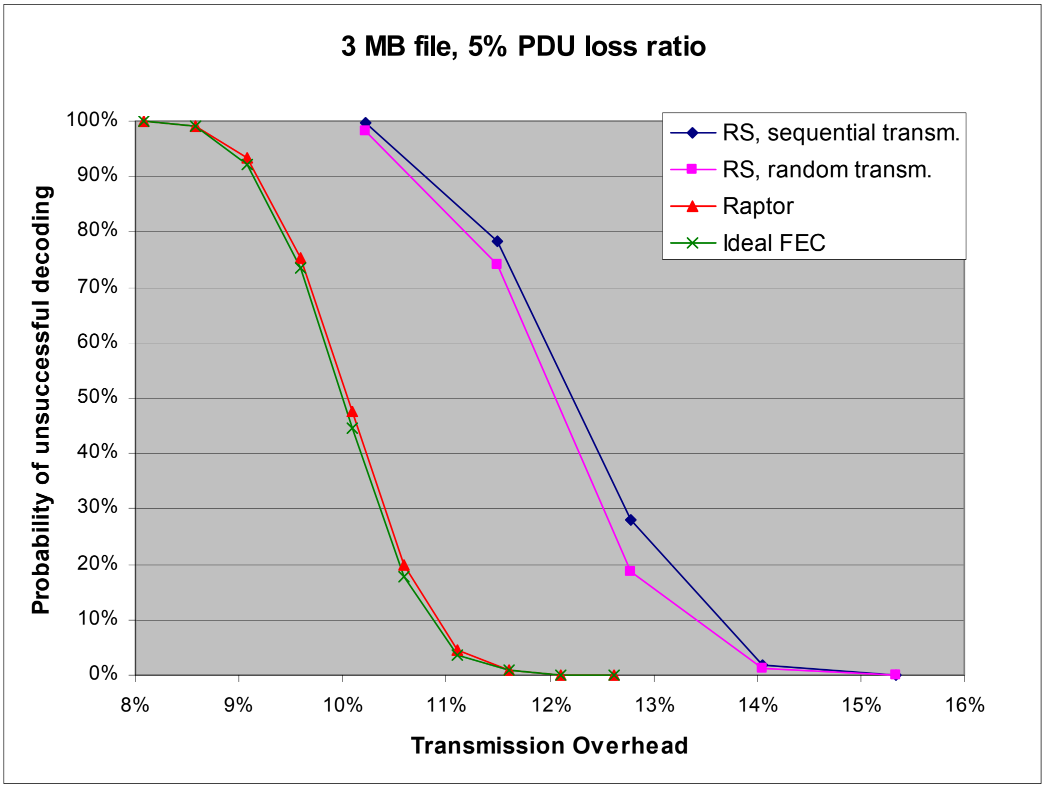
Raptor
Ideal FEC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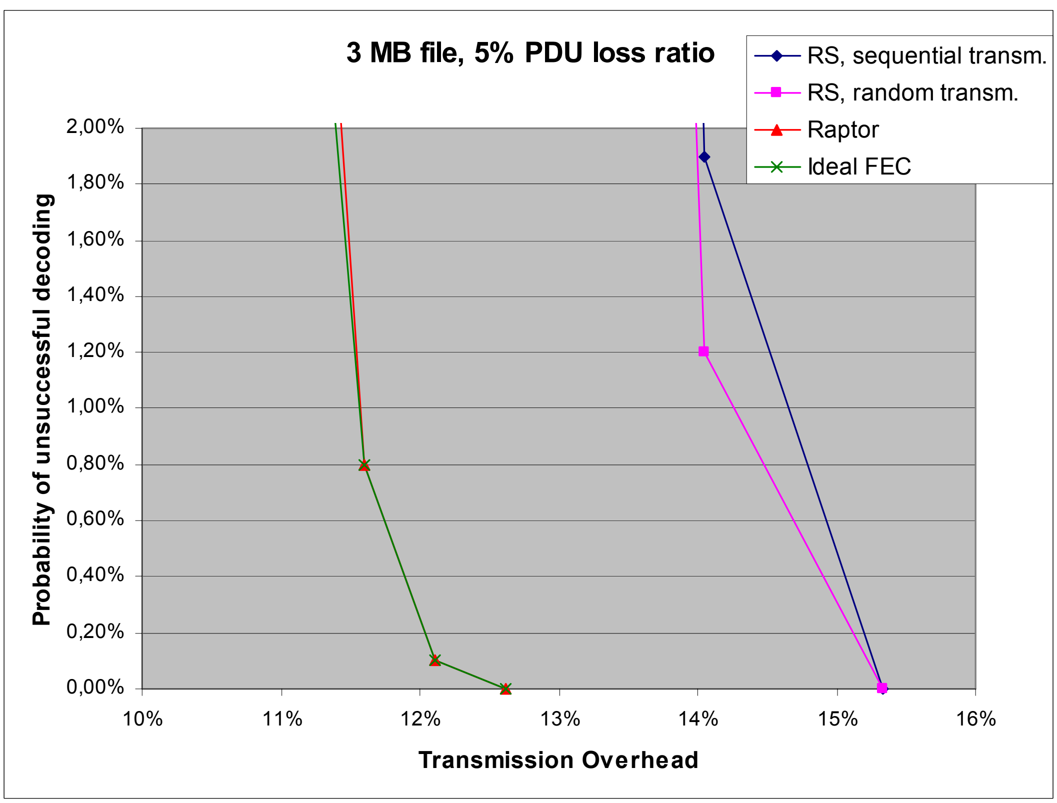
16%
Transmission Overhead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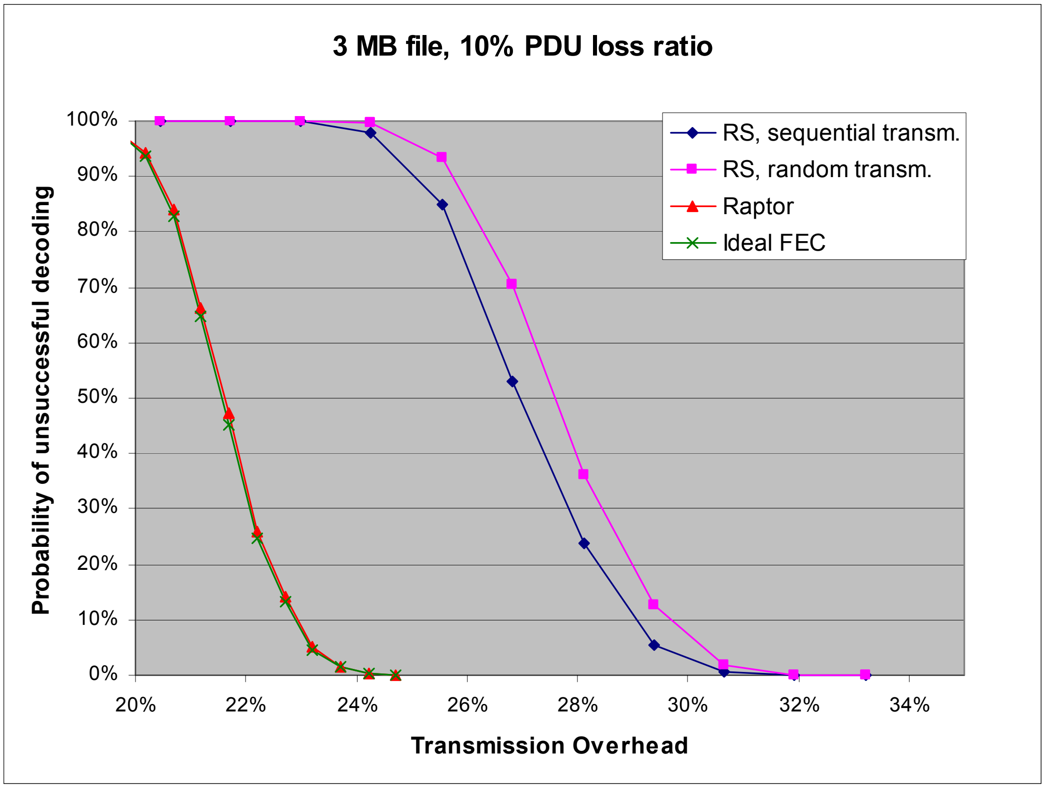
Transmission Overhead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Transmission Overhead
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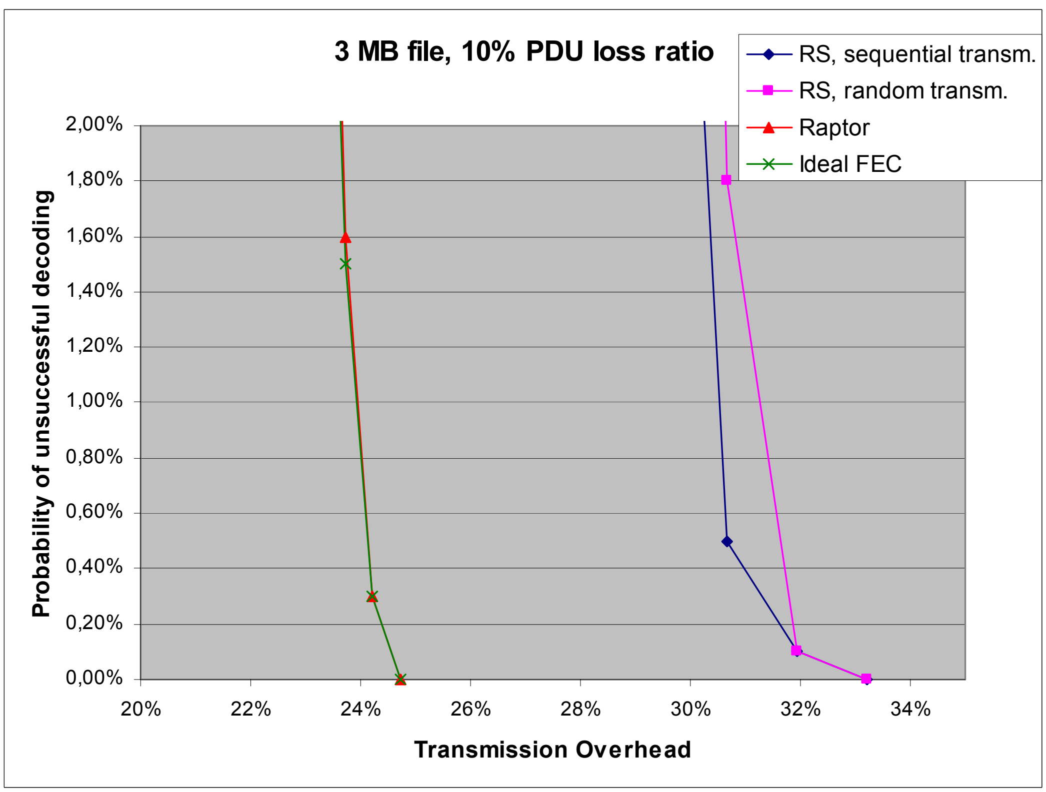
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32%
34%

The following table gives an indication about the effort to be spent for point-to-point repair services over dedicated channels in case decoding fails and including the case transmission is performed without any FEC. The last column contains for each user under certain reception conditions (1%, 5%, and 10% PDU loss) the average number of packets to be repaired by a repair service over dedicated channels. From these figures the evidence of FEC is clearly justified. Only for very small user groups and good transmission conditions (low PDU loss ratio) such a point-to-point repair service may be less costly.

Error trace file	number of simulations (users)	average PDU loss ratio	average SDU loss ratio	Packets to repair for all users	**average number of packets to repair per UE**
Download 100 kB file					
Tr_PDU640_SDU556_CCL0_PLP0.01.trc	10000	1,00%	1,87%	37372	**3,74**
Tr_PDU640_SDU556_CCL0_PLP0.05.trc	10000	5,00%	9,13%	182608	**18,26**
Tr_PDU640_SDU556_CCL0_PLP0.1.trc	10000	10,00%	17,77%	355305	**35,53**
Download 500 kB file					
Tr_PDU640_SDU556_CCL0_PLP0.01.trc	5000	1,00%	1,88%	93953	**18,79**
Tr_PDU640_SDU556_CCL0_PLP0.05.trc	5000	5,00%	9,10%	455143	**91,03**
Tr_PDU640_SDU556_CCL0_PLP0.1.trc	5000	10,00%	17,75%	887393	**177,48**
Download 3MB file					
Tr_PDU640_SDU556_CCL0_PLP0.01.trc	1000	1,00%	1,87%	114718	**114,72**
Tr_PDU640_SDU556_CCL0_PLP0.05.trc	1000	5,00%	9,11%	559797	**559,80**
Tr_PDU640_SDU556_CCL0_PLP0.1.trc	1000	10,00%	17,75%	1090513	**1090,51**