On Unequal Error Protection Raptor Codes

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Introduction

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- Raptor codes are an extension of LT codes which are the first practical realization of fountain codes
- Raptor codes improved on LT codes by providing linear encoding and decoding costs.

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- The precode produces m intermediate symbols
- The m intermediate symbols are then encoded by an LT-type encoder to produce n output symbols

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Decoding

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- After a sufficient number of symbols are collected. The LT part of the decoder attempts to reconstruct the original m intermediate symbols
- Then, the m intermediate symbols are passed to the LDPC part of the decoder to recover the original k symbols

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- contrary to Equal Error Protection (EEP), Unequal Error Protection (UEP) provides different parts of source data with different and unequal error correction capability according to their relative importance
- UEP versions of many channel codes exist, and attempts to produce better such codes continue
- UEP codes usually divide the source data into two categories:
  - More Important Bits (MIB)
  - Less Important Bits (LIB)

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- Therefore, the average BER of UEP codes are usually higher compared to EEP codes

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- A good question is "which method can lead to better overall performance, in terms of achieved BER?"
- We studied UEP Raptor codes in search of the answer

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Designs used as models

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- One of the UEP Raptor code designs we implemented was combining UEP LDPC code as precode with EEP LT part
- We compared it with an UEP Raptor code with the structure of; EEP LDPC code and UEP LT part

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- The collected encoding symbols are first decoded by the LT part to retrieve m intermediate symbols
- Next, the length-m block is passed to the LDPC decoder part
- The performance of the LDPC code partly depends on the performance of the LT part
- The BER of the length-m block decoded by the LT decoder and then passed to the LDPC decoder affects the ability of the LDPC part to recover erased bits
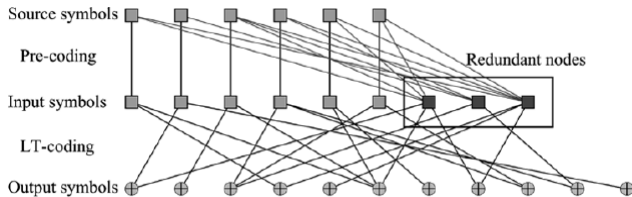
Figure: Graphical representation of Raptor codes.

- Particularly, considering that LDPC decoder uses belief propagation algorithm (BPA)
- The less erroneous information propagates through the decoding graph, more symbols will be decoded correctly
- therefore the question of, whether applying the UEP property on the LT or LDPC part of Raptor codes, becomes the following question:
- Which method passes a lower BER from the LT part to LDPC part of the decoder.

UEP Raptor codes

- UEP LT codes have a higher average BER compared to EEP LT codes with the same output degree distribution and code length over the same overhead range
- The advantage of using EEP LT with lower average BER clear.

Reasoning
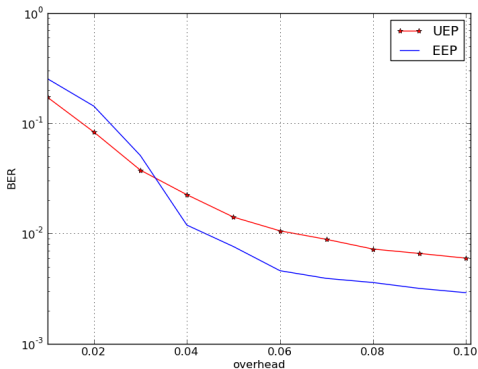
Combining the arguments above, we can deduce the disadvantage of using UEP LT codes to design UEP Raptor codes compared to using EEP LT code and applying the UEP on the LDPC part because:

- UEP LT codes have higher average BER compared to EEP LT codes, which means they pass a higher number of erasures to the LDPC part of the decoder
- Higher number of erasures in the passed length-m intermediate symbols will negatively affect the performance of the LDPC decoder
- Alternatively, even a few extra recovered bits in the m intermediate symbols can lead to a chain reaction that may lead to the recovery of the entire message

Motivated by the reasoning above we put the proposed designs to the test and compared the results with those of the alternative design.
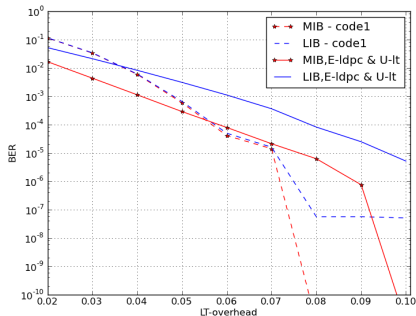

Figure: BER performance of UEP Raptor codes for LDPC code rate $= 0.95$.

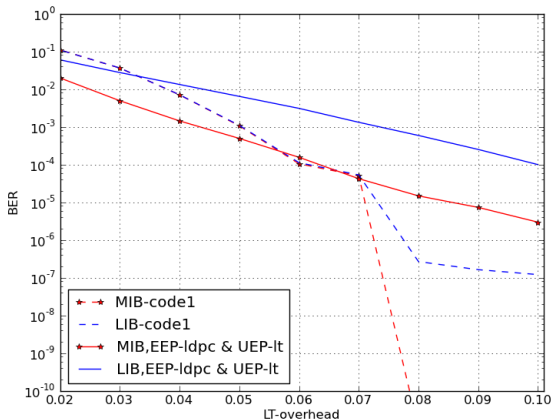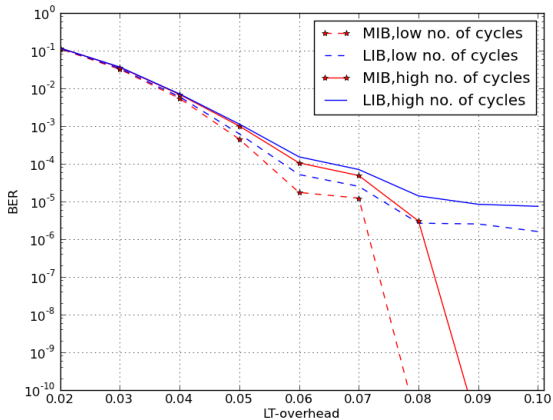Figure: BER performance of UEP Raptor codes for LDPC code rate $= 0.95$.

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Conclusions

- We studied in this paper the design of UEP Raptor codes, with the objective of comparing two designs of UEP Raptor codes:
  - UEP precode with EEP LT code
  - EEP precode with UEP LT code.

- By reasoning, analysis and simulation we reach that designing UEP Raptor codes with UEP precode can lead to achieving lower BER for both MIB and LIB.

- It boils down to to the important detail that this design has the advantage of passing lower BER from the LT part to the precode part of the Raptor decoder.