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Polar Codes with Local-Global Decoding

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Introduction

We present a polar code construction that supports both local and global decoding. Local decoding allows random access to subblocks of the full code block.

1KB	1KB	1KB	1KB
4KB			

When local decoding performance is insufficient, global decoding provides improved data reliability. This local-global construction is motivated by practical applications where reduced-latency recovery of subblocks of the coded information is required:

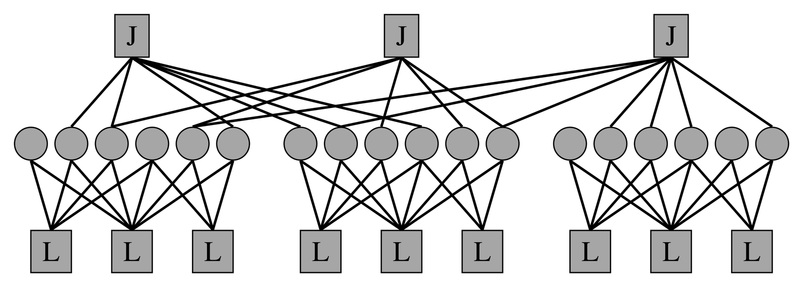
- Advanced multilevel flash memory
- Low-latency wireless communication

A local-global polar decoding architecture is proposed.

- Inner polar codes coupled through a **systematic** auxiliary polar code. [1]
- **Split permutation** maps specific systematic message bits to each inner code.

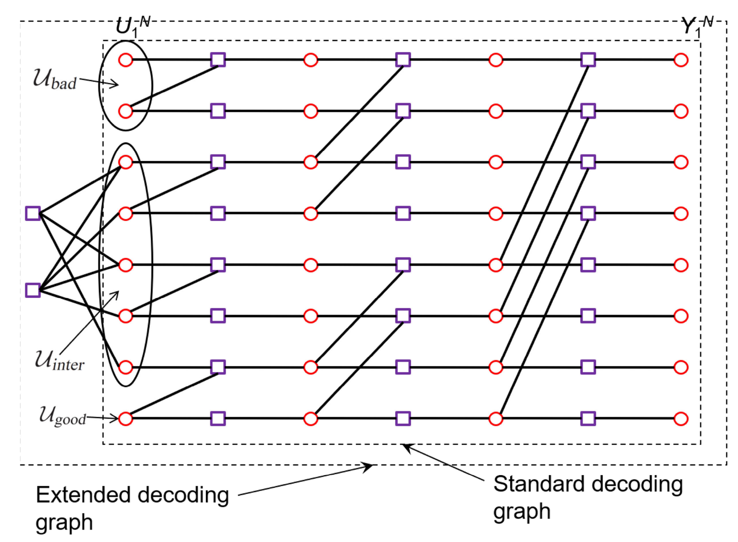
Local-Global LDPC Code [2]

Sub-blocked Tanner graph with 3 subblocks of length 6.
Local check nodes **L** and joint (global) check nodes **J**.



Enhanced BP Decoding [3]

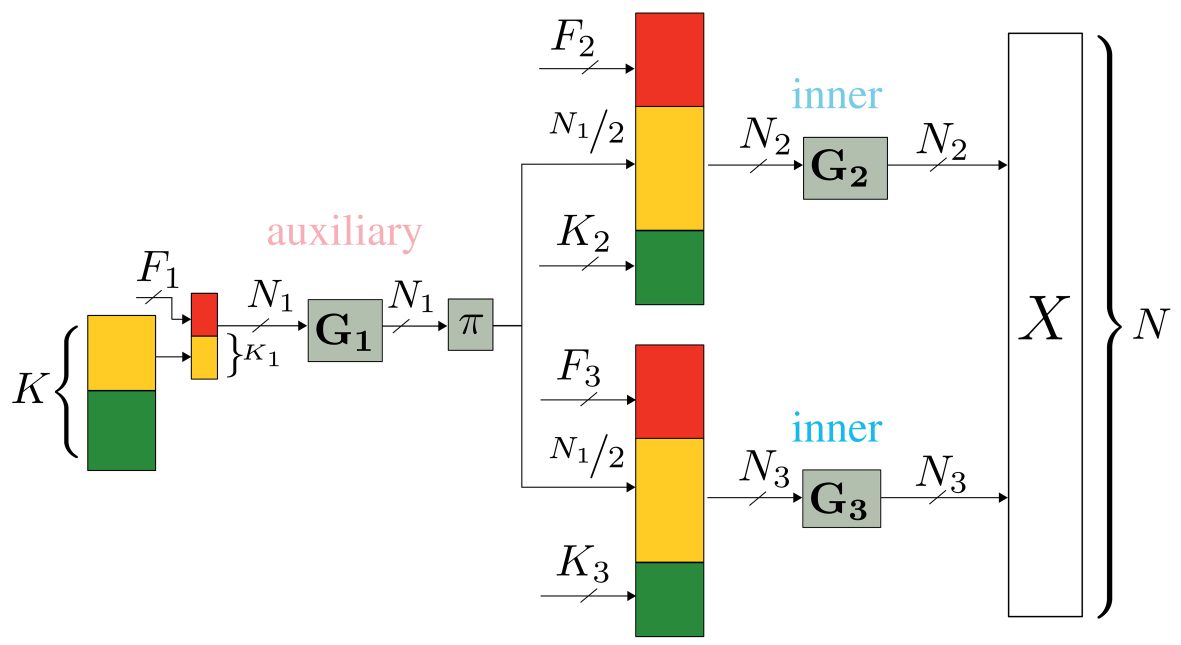
Auxiliary code to protect intermediate quality (semi-polarized) bit-channels.
Enhanced belief-propagation (EBP) decoding on extended factor graph.



Flexible Length Polar Codes [4]

Augmented polar code with auxiliary polar code.
Enhanced BP decoding on extended factor graph.
Flexible length polar code via coupling through auxiliary polar code:

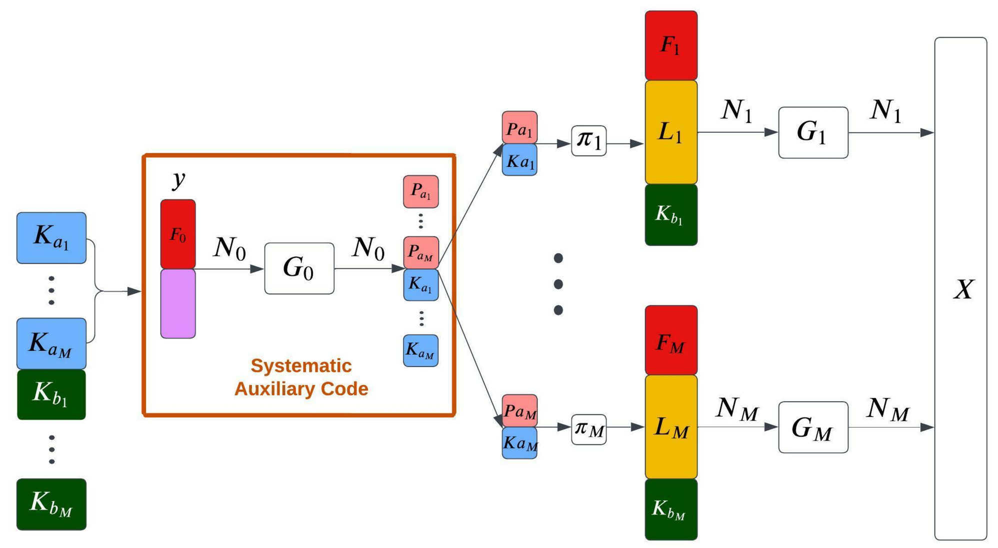
- $R_1 = \frac{K_1}{N_1}$; $R_2 = \frac{K_2 + \frac{N_1}{2}}{N_2}$; $R_3 = \frac{K_3 + \frac{N_1}{2}}{N_3}$
- $R_{total} = \frac{K}{N} = \frac{K_1 + K_2 + K_3}{N_2 + N_3}$



Local-Global Polar Codes

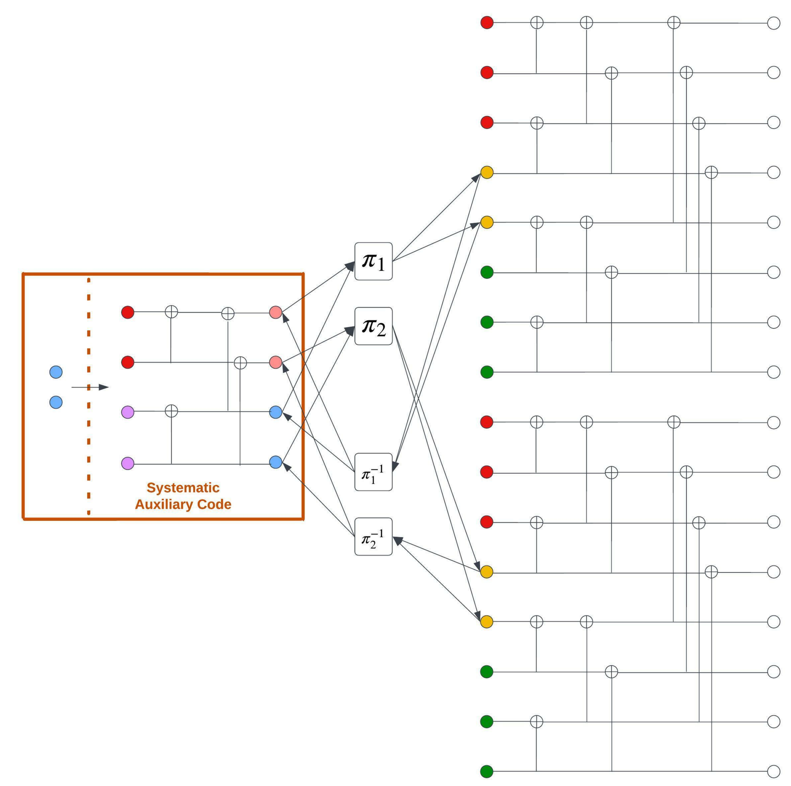
Encoder architecture for local-global polar code.

- Systematic auxiliary polar code.
- Split permutation respects inner code assignments of $K_{a_1}, K_{a_2}, \ldots, K_{a_M}$



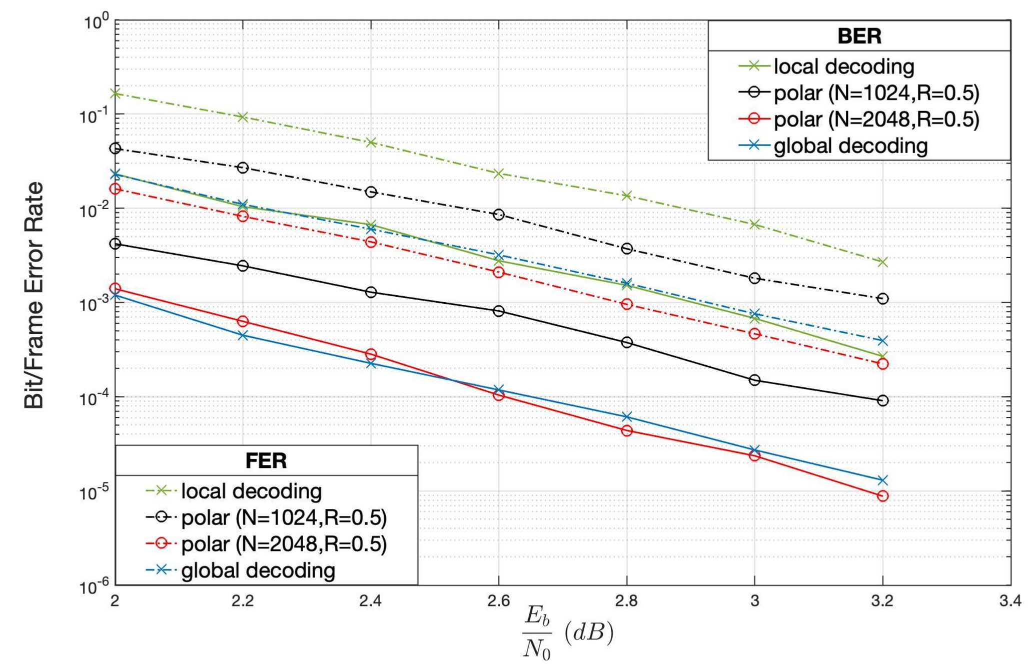
Factor graph for local-global polar **decoding**.

- Enhanced BP decoding.
- Early stopping rule for coupled codes.

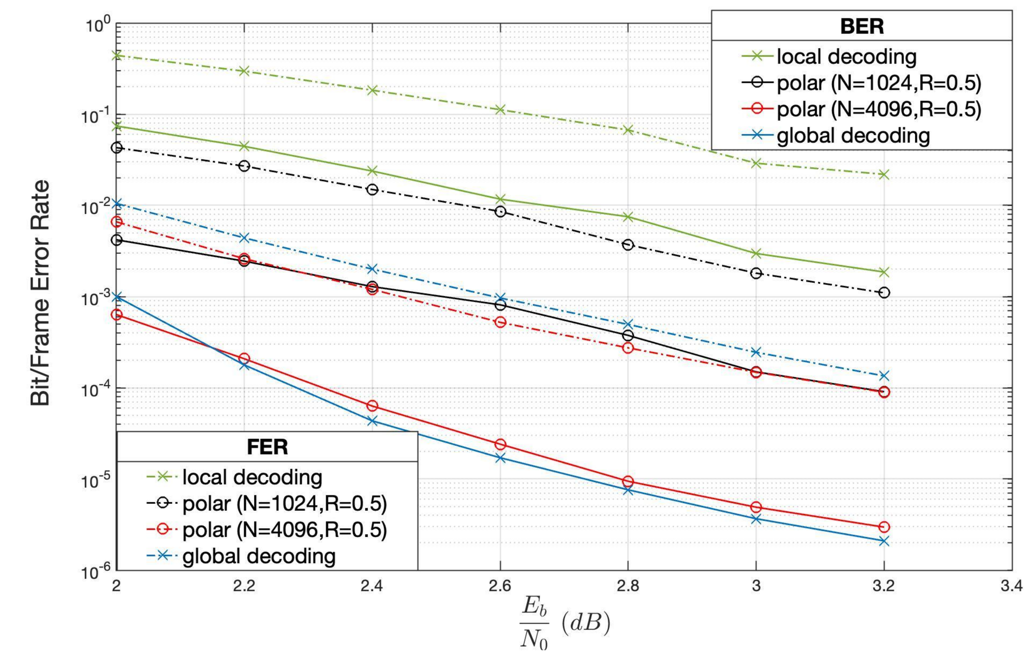


Simulation: local-global decoding with 2,4 inner codes

- $R_{eff} = 0.5$.
- Inner codes $C_j, j = 1, 2$
  - Code C_j message size:
    $M_j = K_{aj} + K_{bj} = 32 + 480 = 512$
  - Code C_j unfrozen frame size:
    $K_j = M_j + P_{aj} = 512 + 32 = 544$
  - Code C_j total frame size:
    $N_j = K_j + F_j = 544 + 480 = 1024$
- Systematic auxiliary code C_0
  - Code C_0 rate:
    $R_0 = K_a/(K_a + F_0) = 64/128 = 0.5$



- $R_{eff} = 0.5$.
- Inner codes $C_j, j = 1, 2, 3, 4$
  - Code C_j message size:
    $M_j = K_{aj} + K_{bj} = 64 + 448 = 512$
  - Code C_j unfrozen frame size:
    $K_j = M_j + P_{aj} = 512 + 64 = 576$
  - Code C_j total frame size:
    $N_j = K_j + F_j = 576 + 448 = 1024$
- Systematic auxiliary code C_0
  - Code C_0 rate:
    $R_0 = K_a/(K_a + F_0) = 256/512 = 0.5$



References

[1] E. Arikan, "Systematic polar coding," *IEEE Commun. Letters*, August 2011.
[2] E. Ram and Y. Cassuto, "LDPC codes with local and global decoding," May 2019. arXiv:1801.03951
[3] J. Guo, et al., "Enhanced belief propagation decoding of polar codes through concatenation," ISIT 2014.
[4] A. Elkelesh, et al., "Flexible length polar codes through graph based augmentation," SCC 2017.