Blind Detection of Polar Codes

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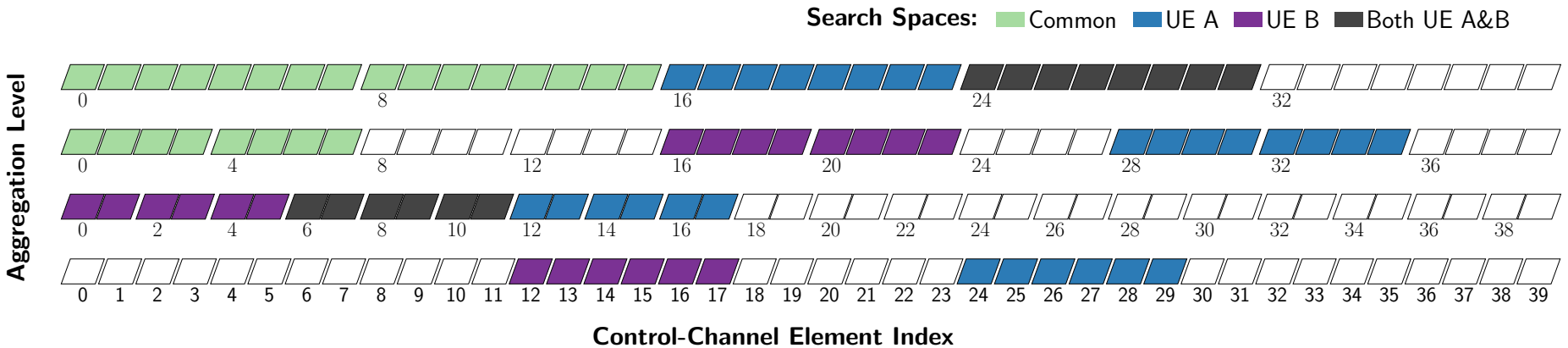
Control Channel Detection for 5G

- For each UE, many slots can contain a control message
- Control messages are encoded with a polar code
- Don't know in advance...
  - if a location contains a control message
  - the polar-code parameters used for encoding



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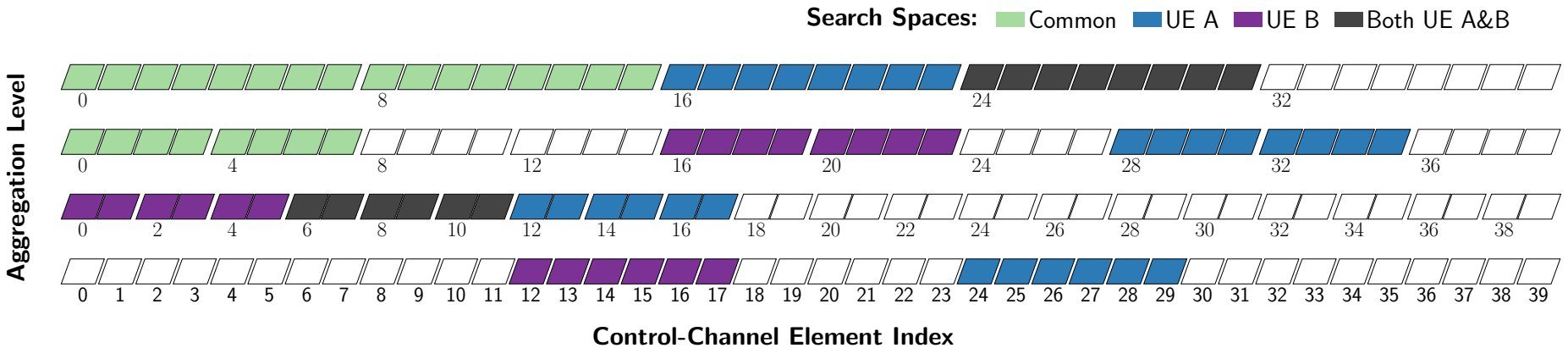

Large search space, what can we do?

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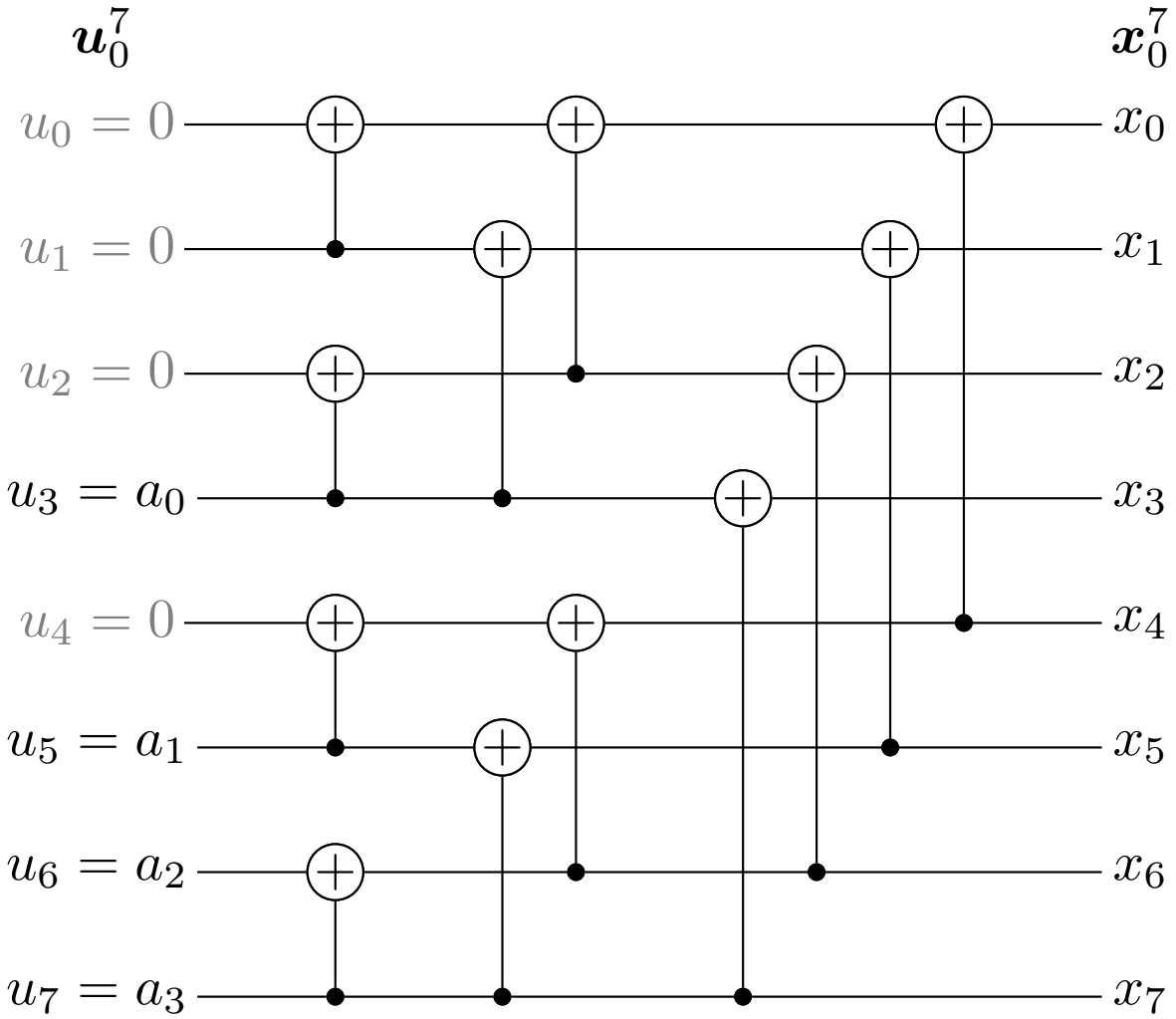
How should we define that metric?

About Polar Codes

Polar Codes – Encoding



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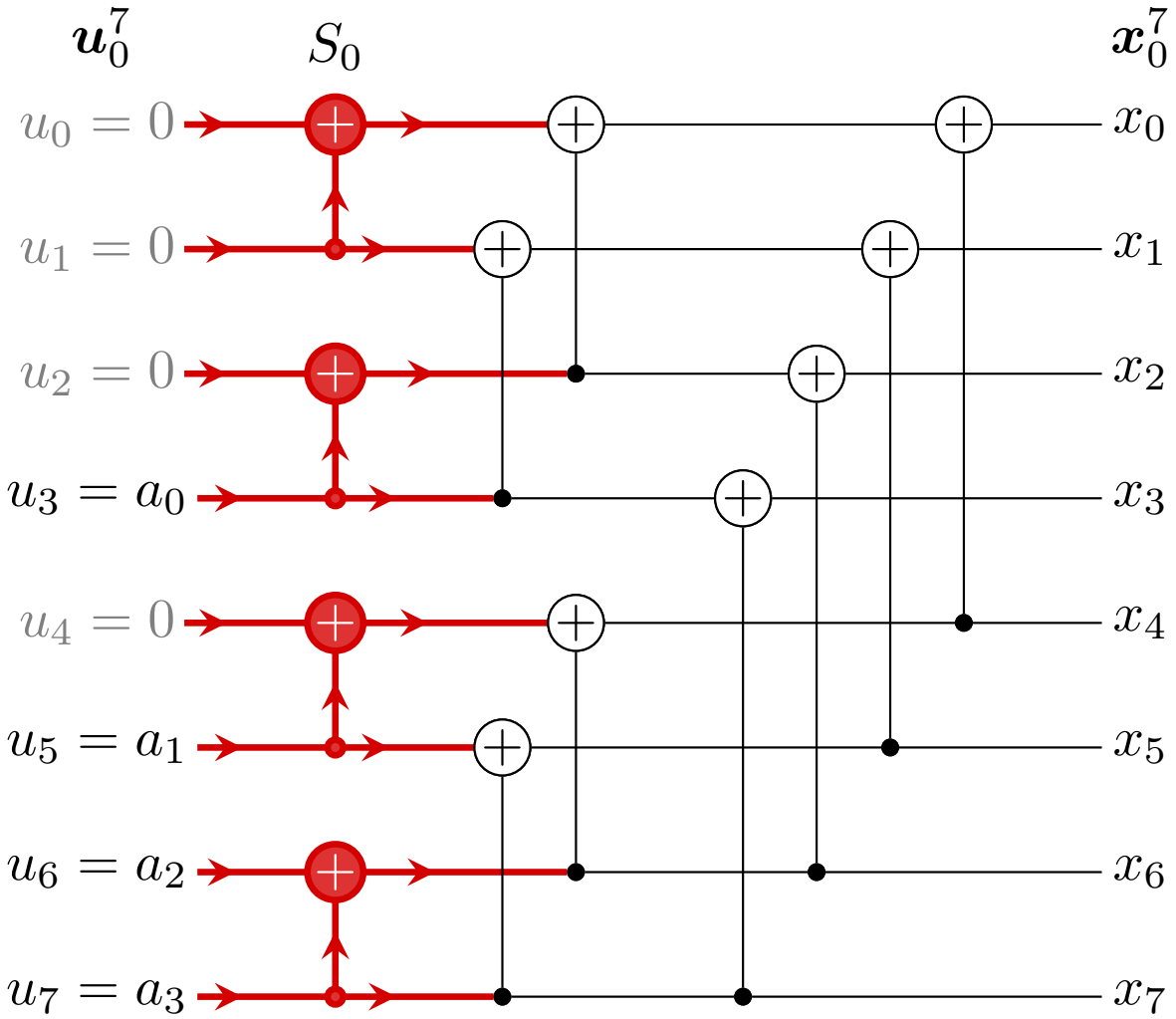

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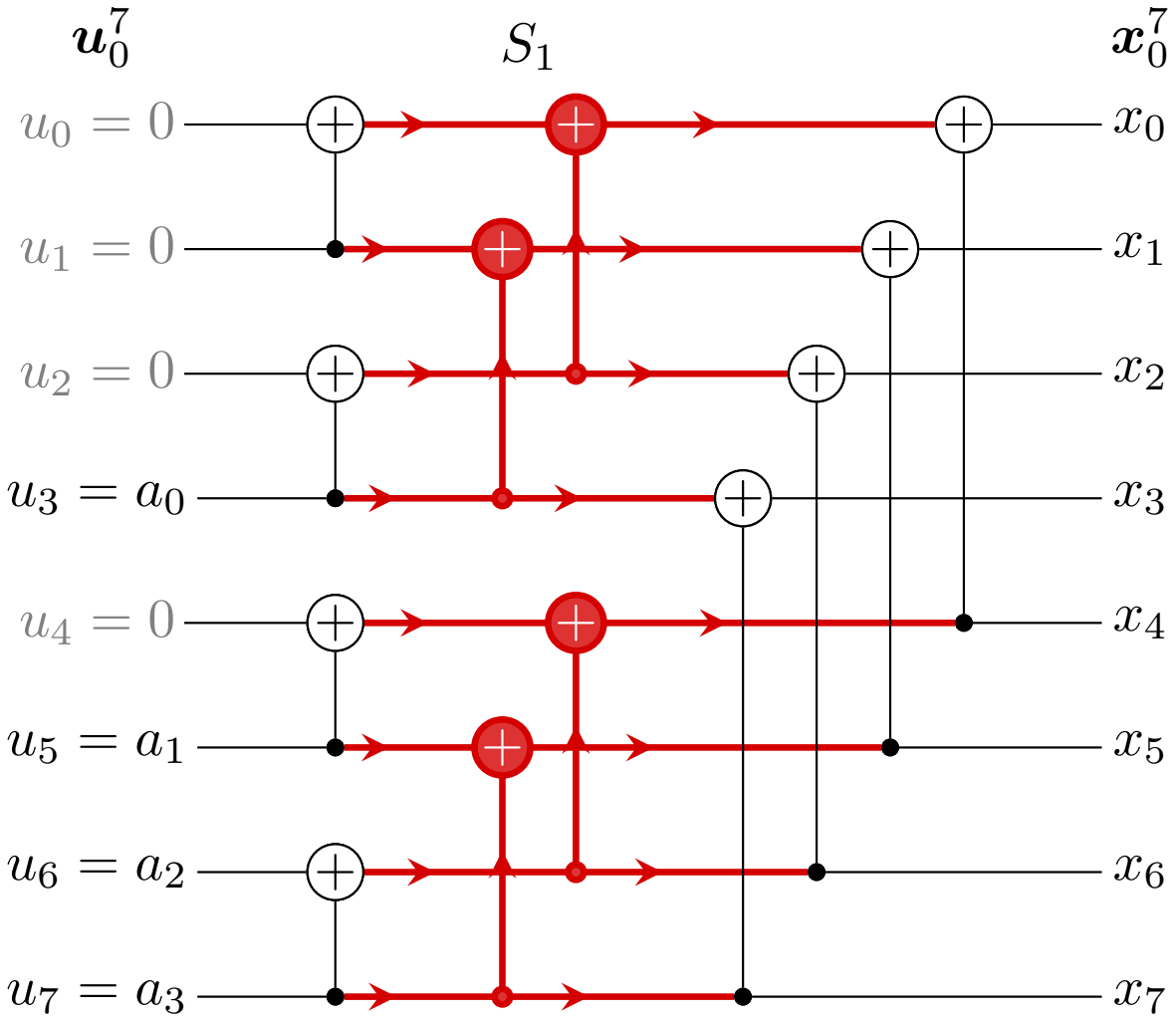

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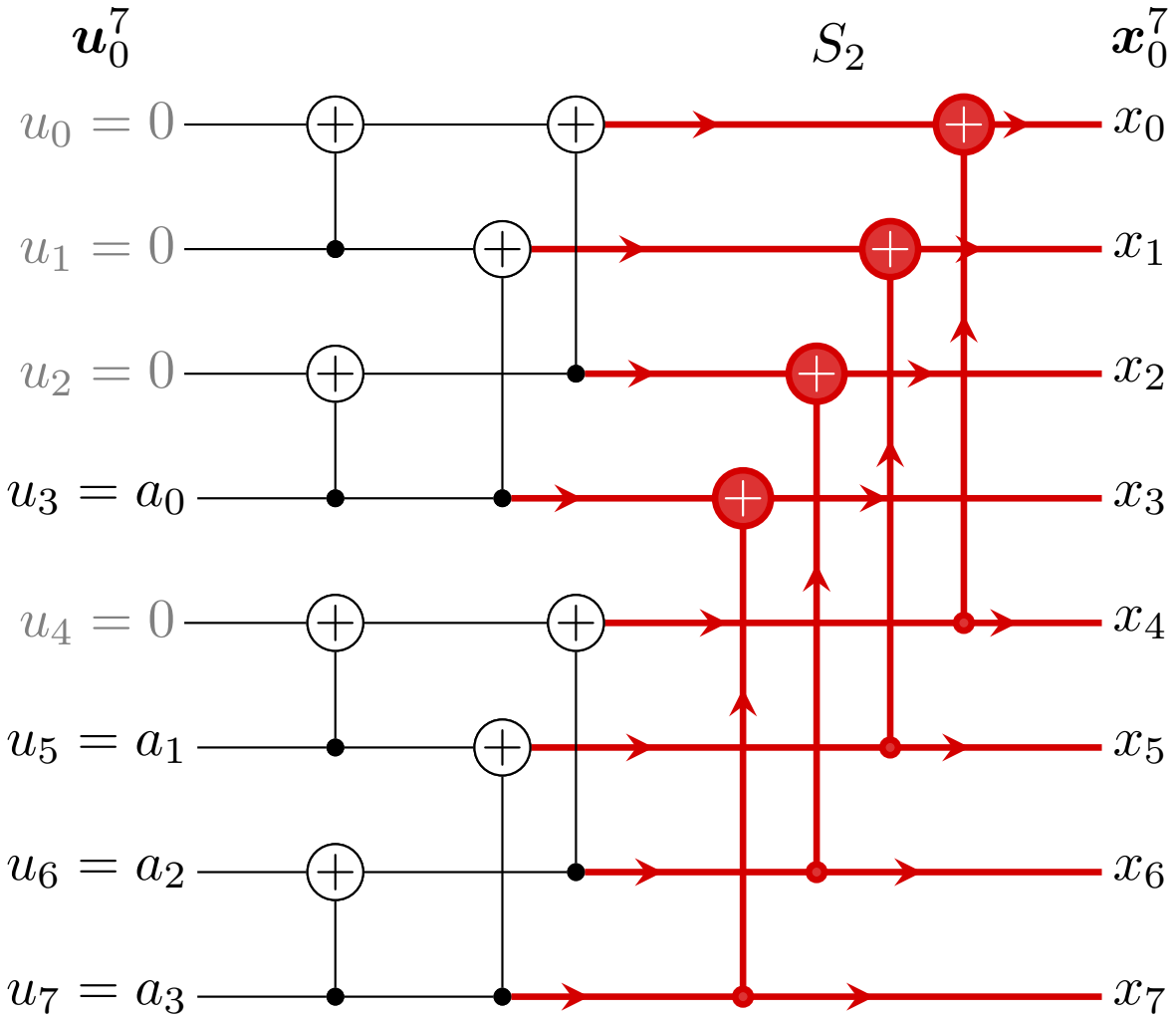
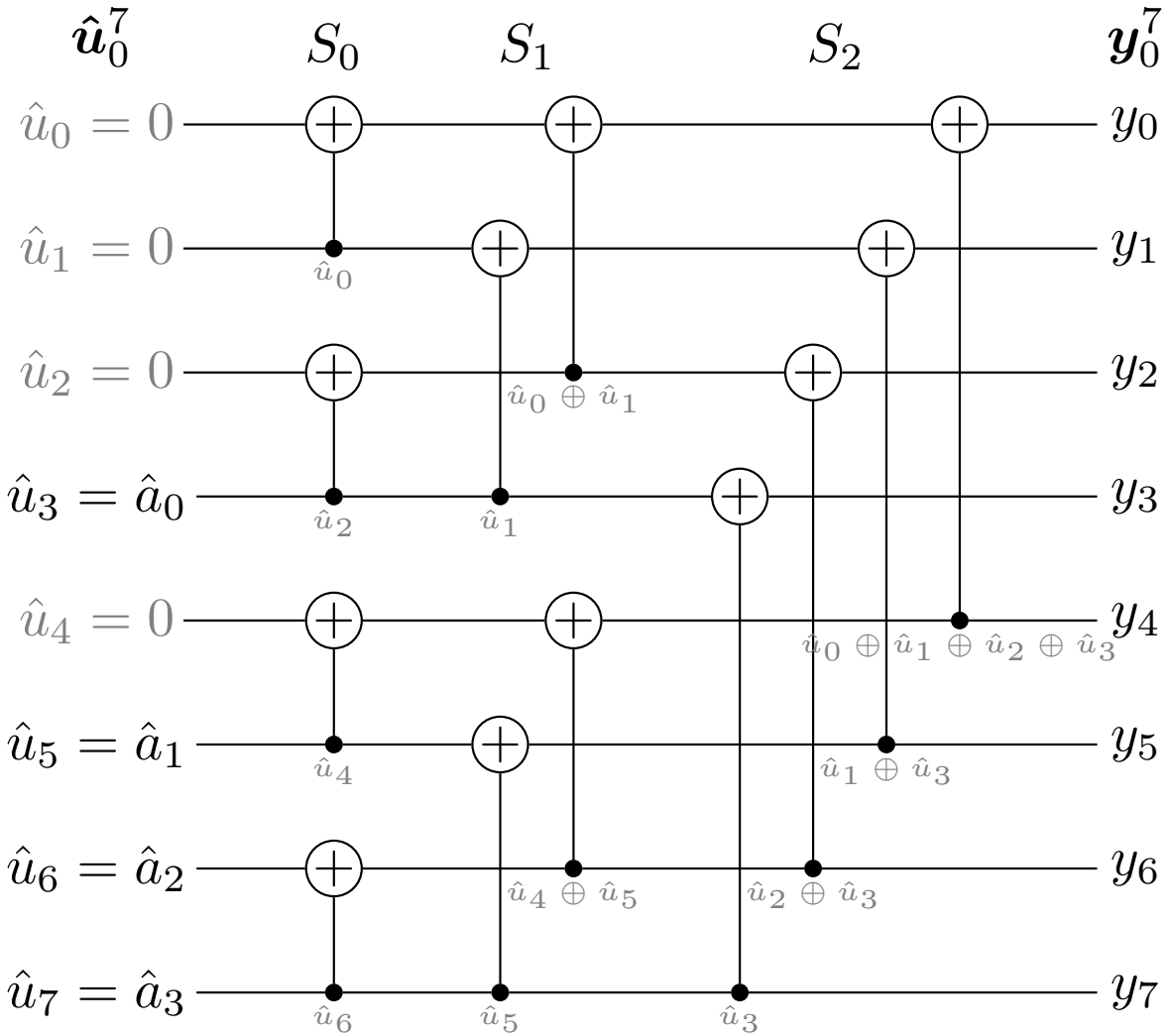


Polar Codes – Successive-Cancellation Decoding



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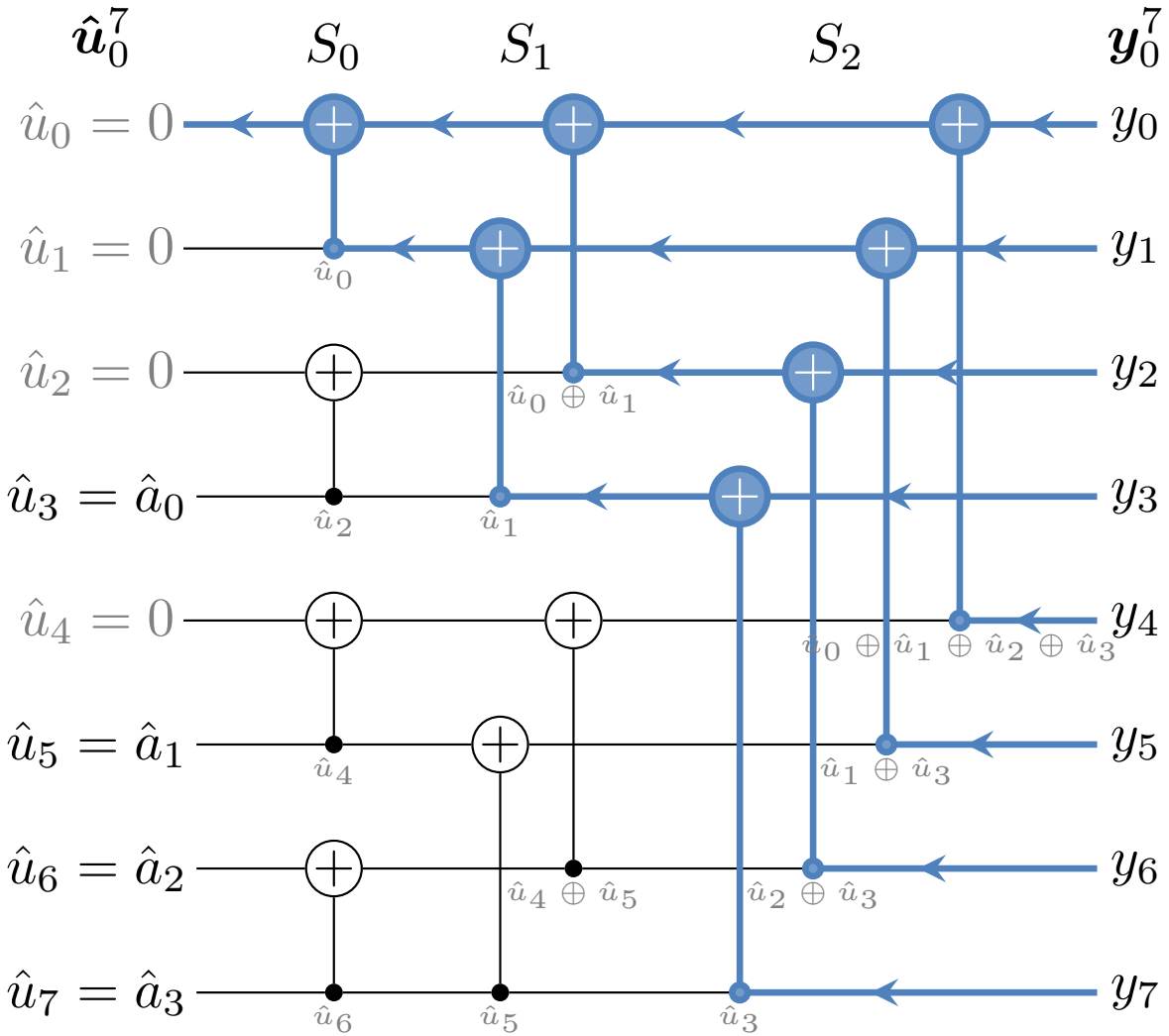

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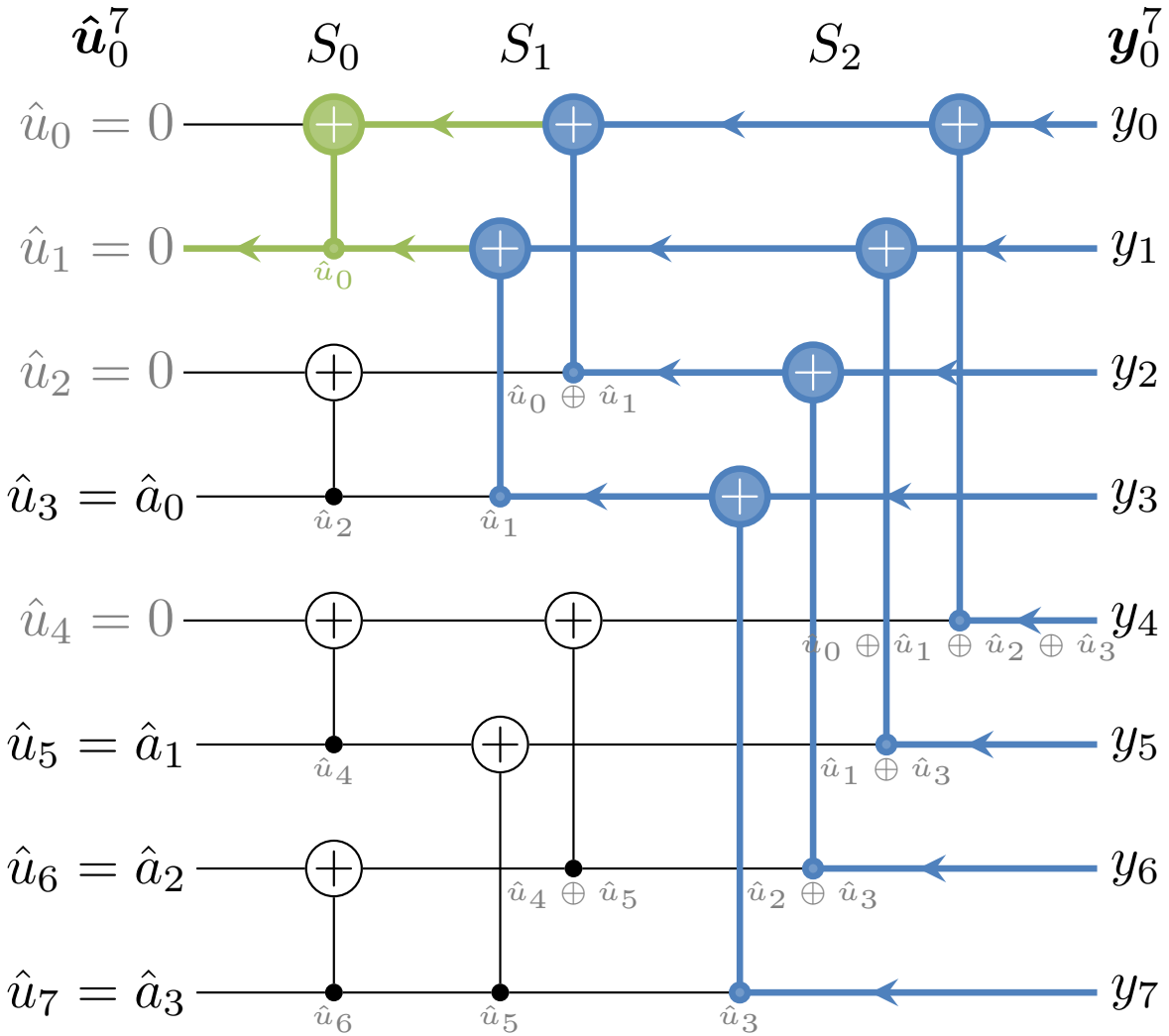

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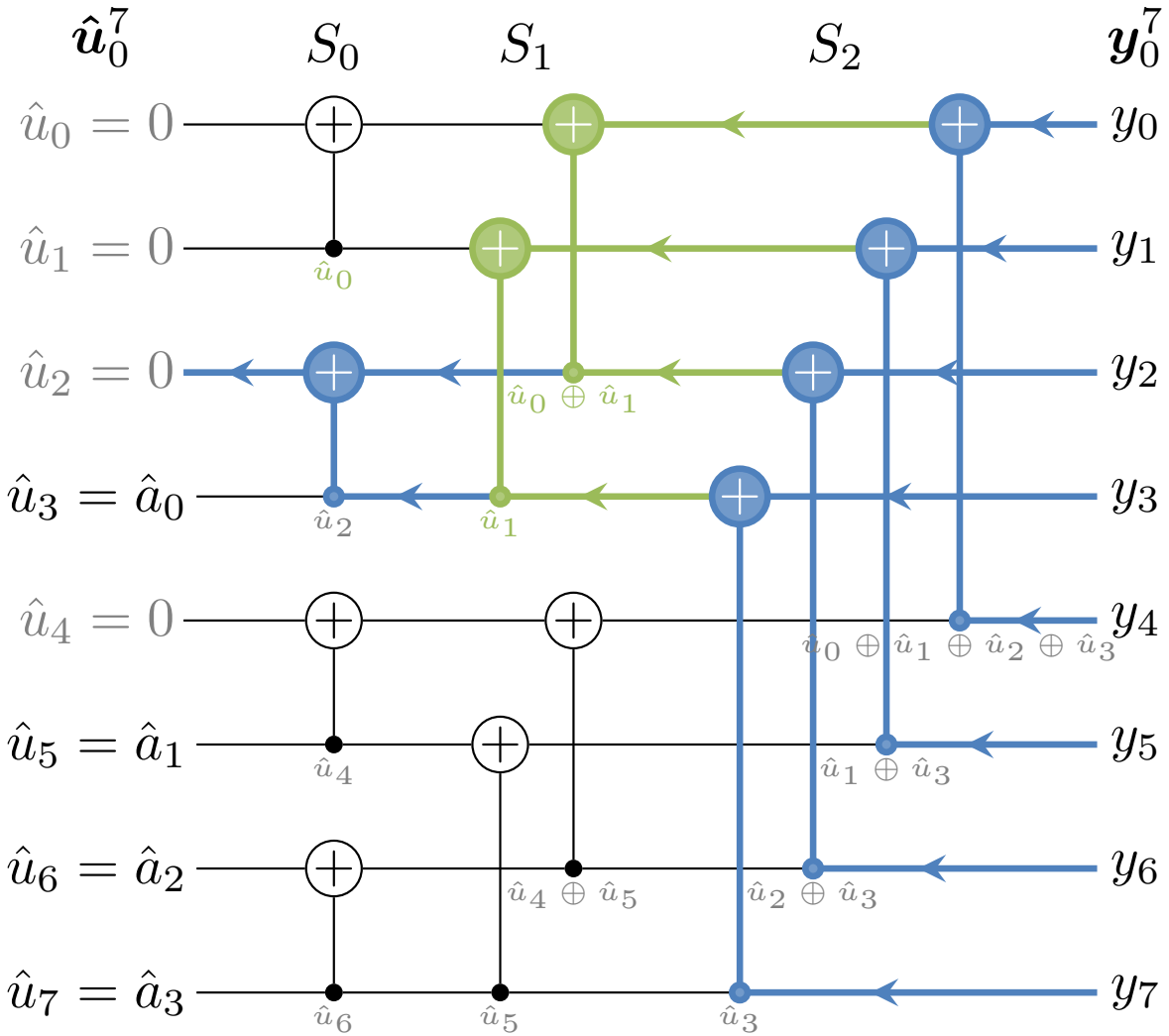

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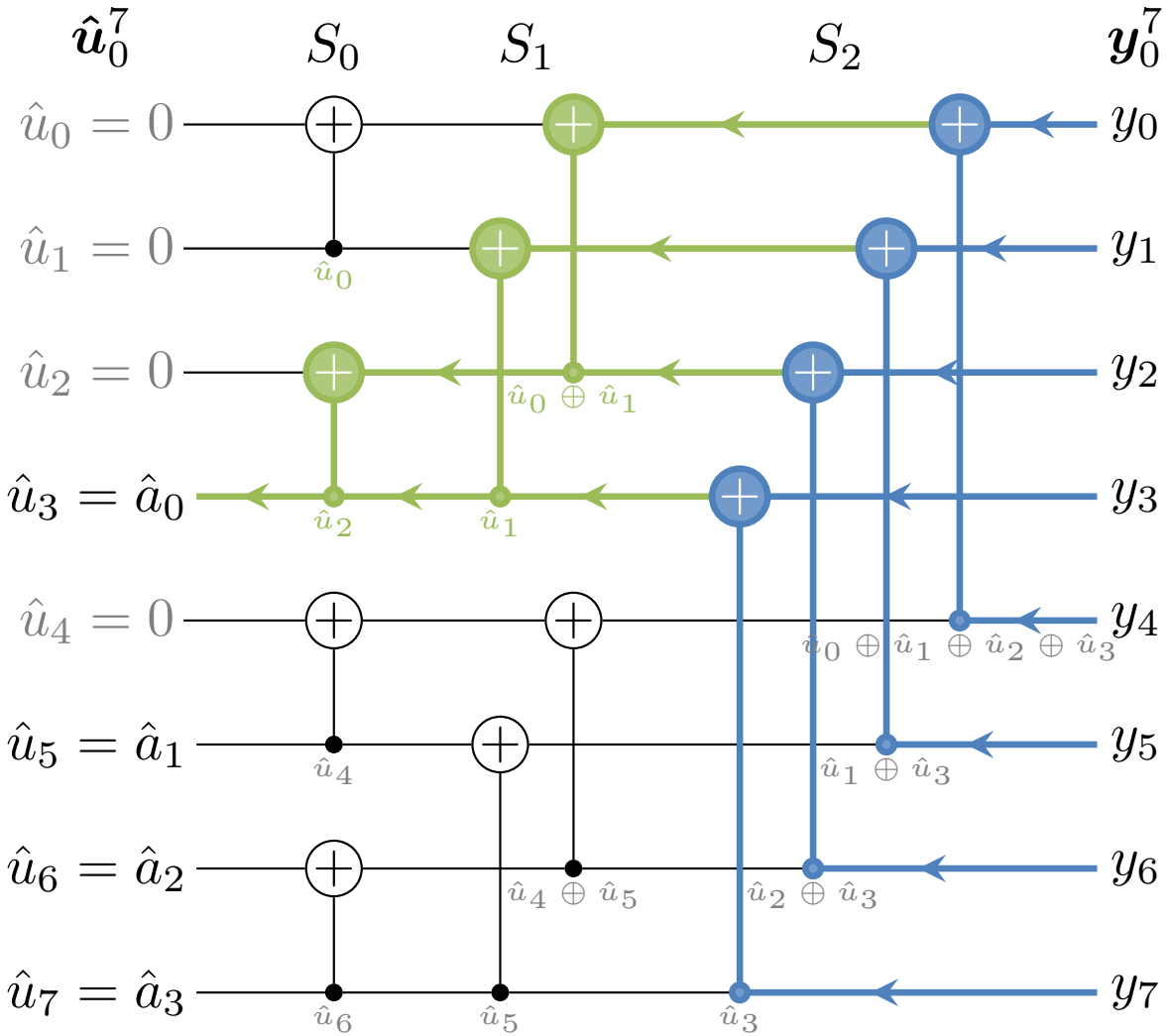

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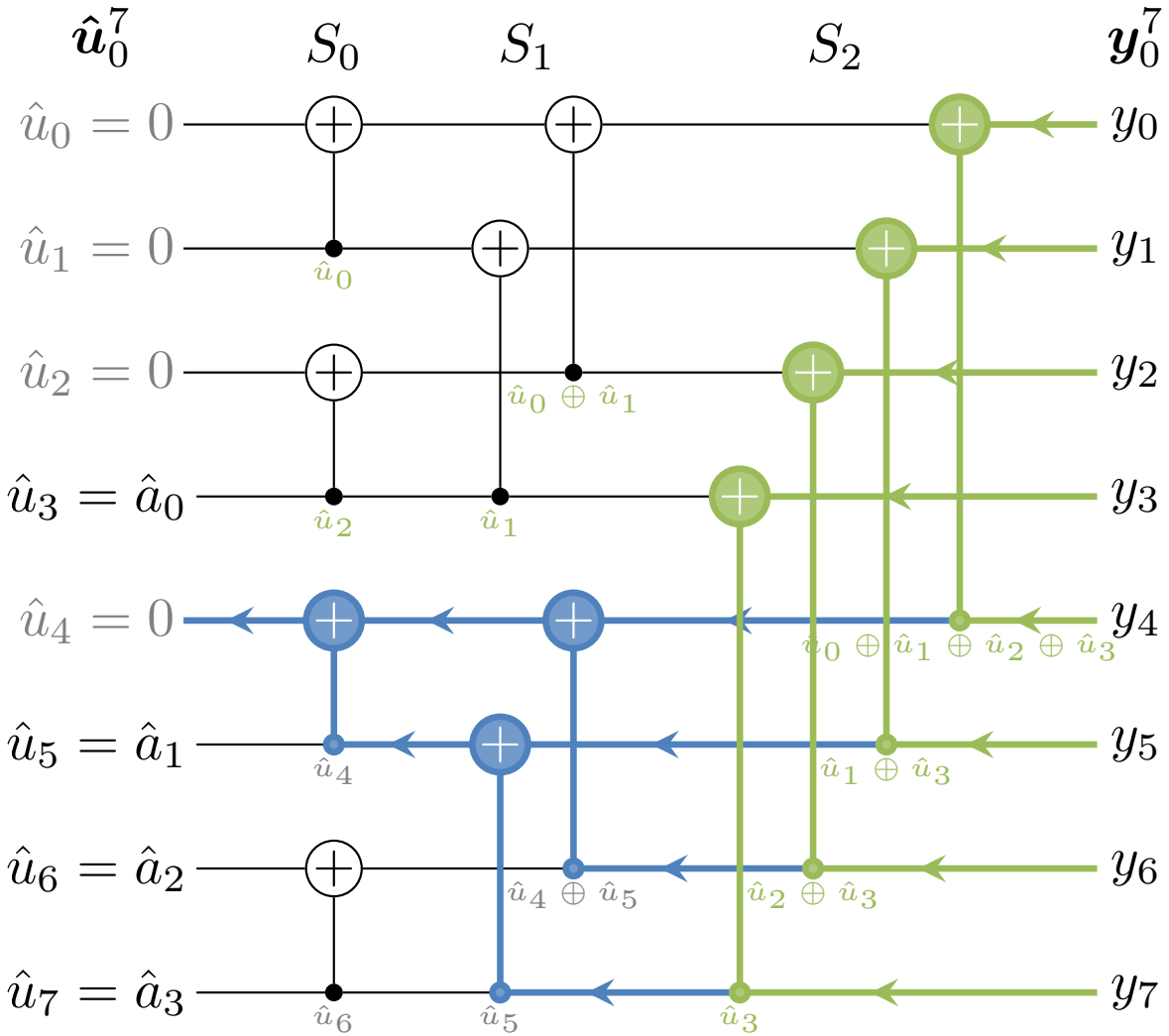

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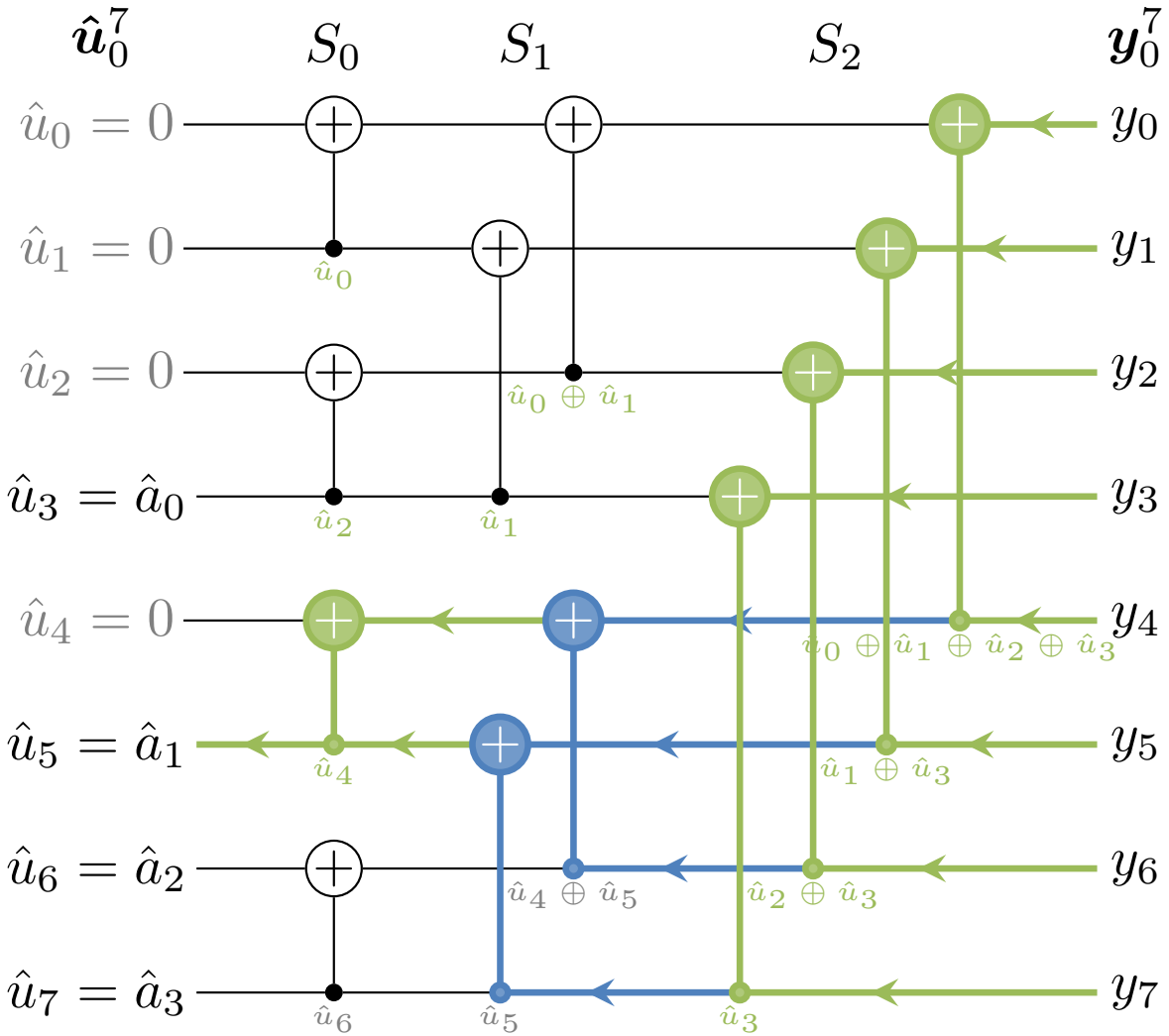

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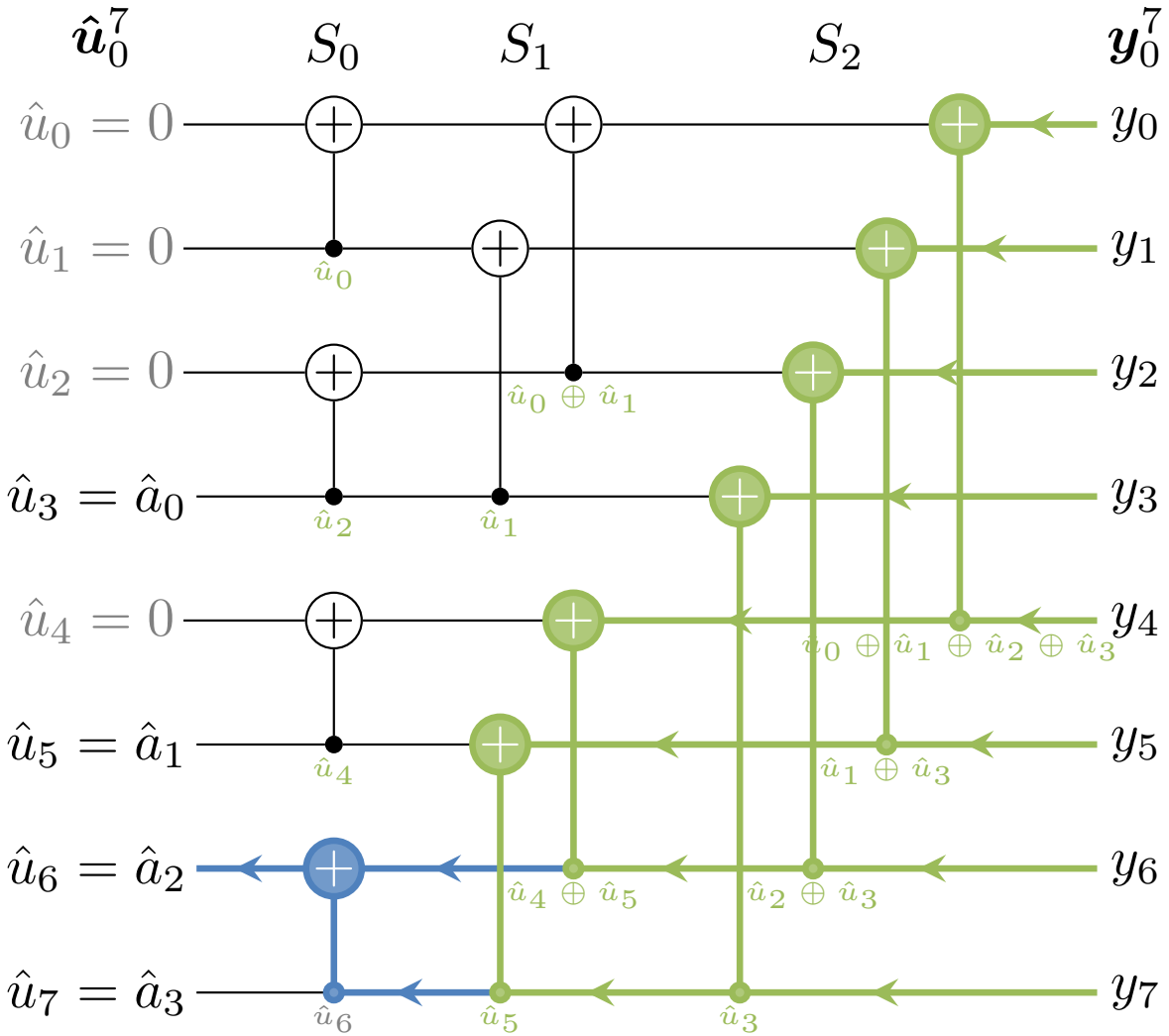

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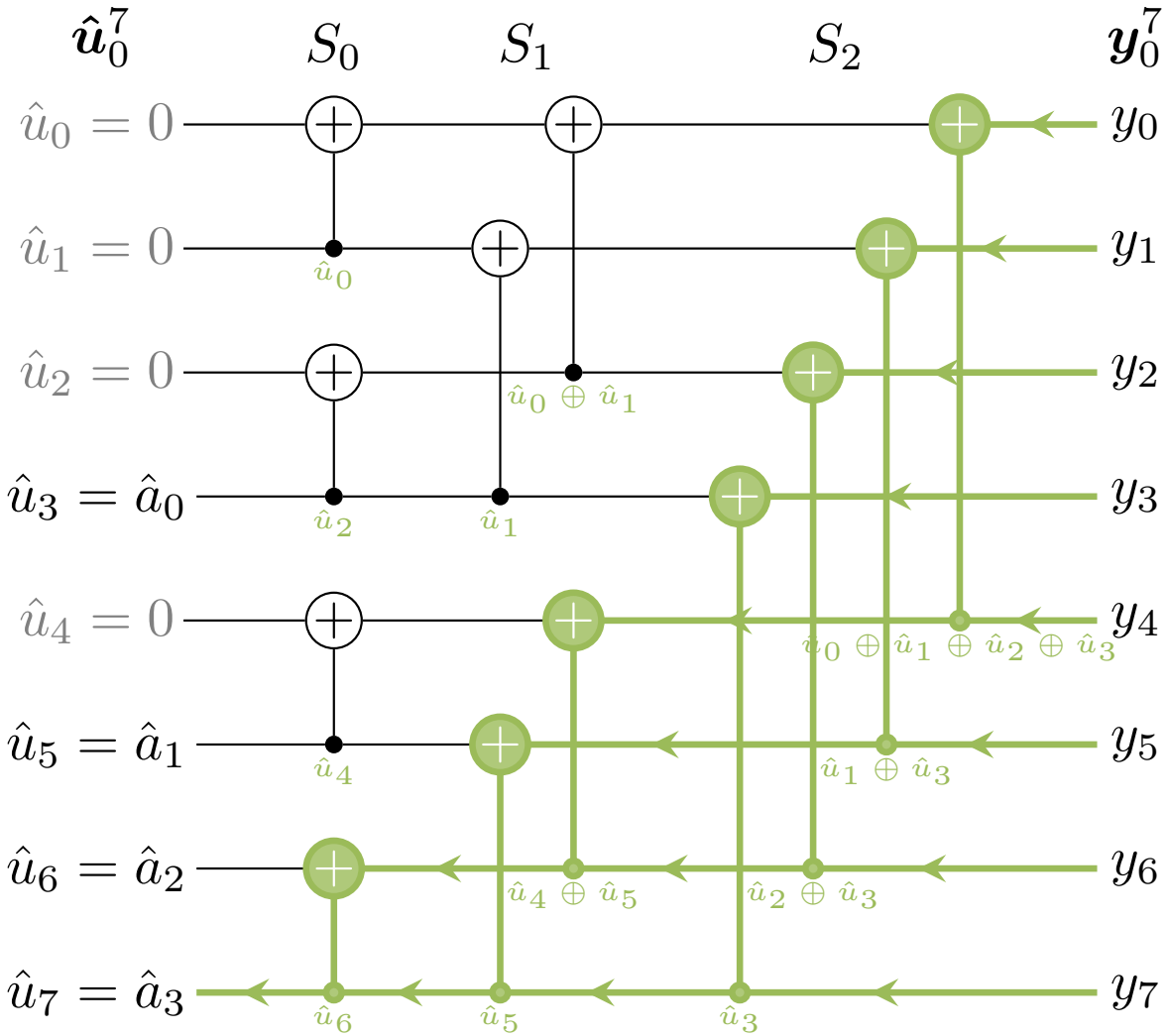

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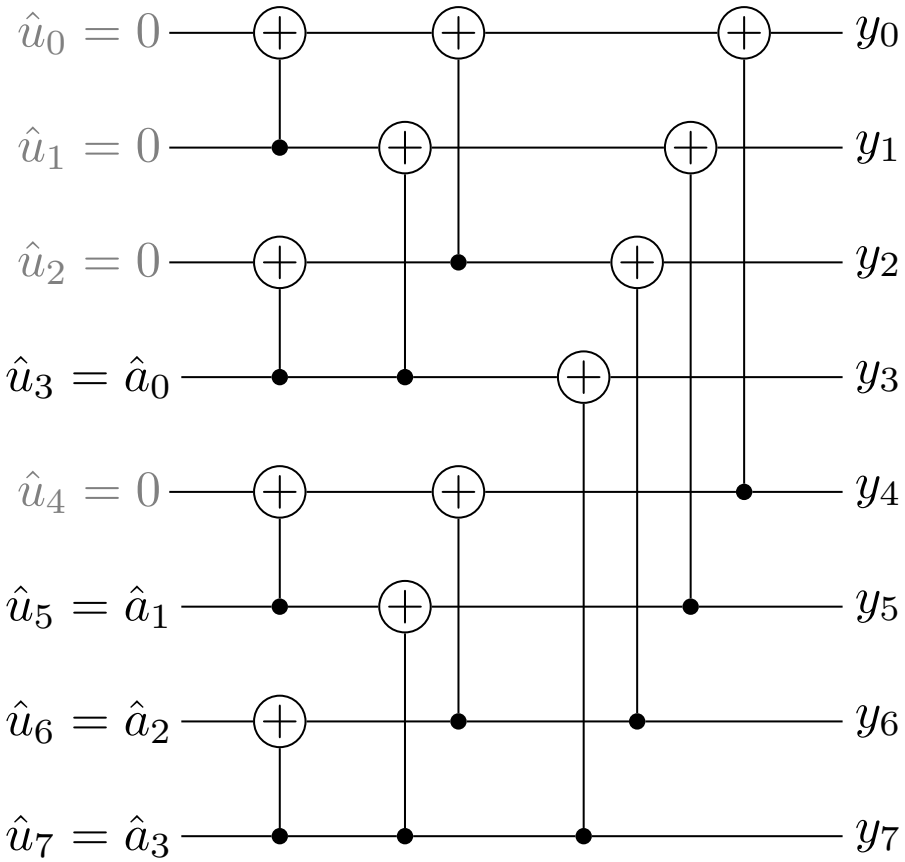

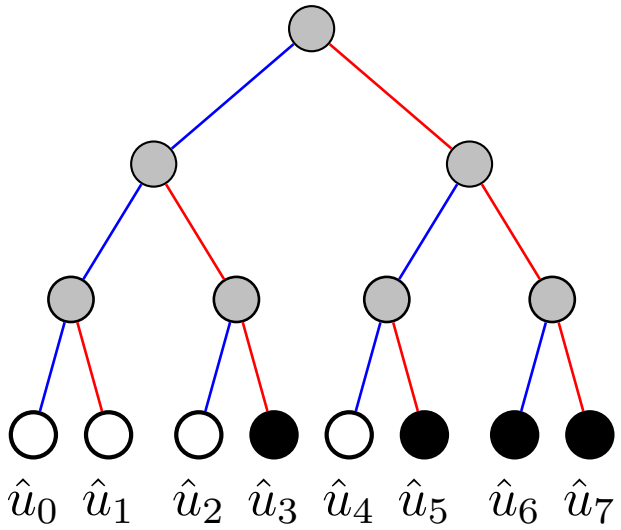

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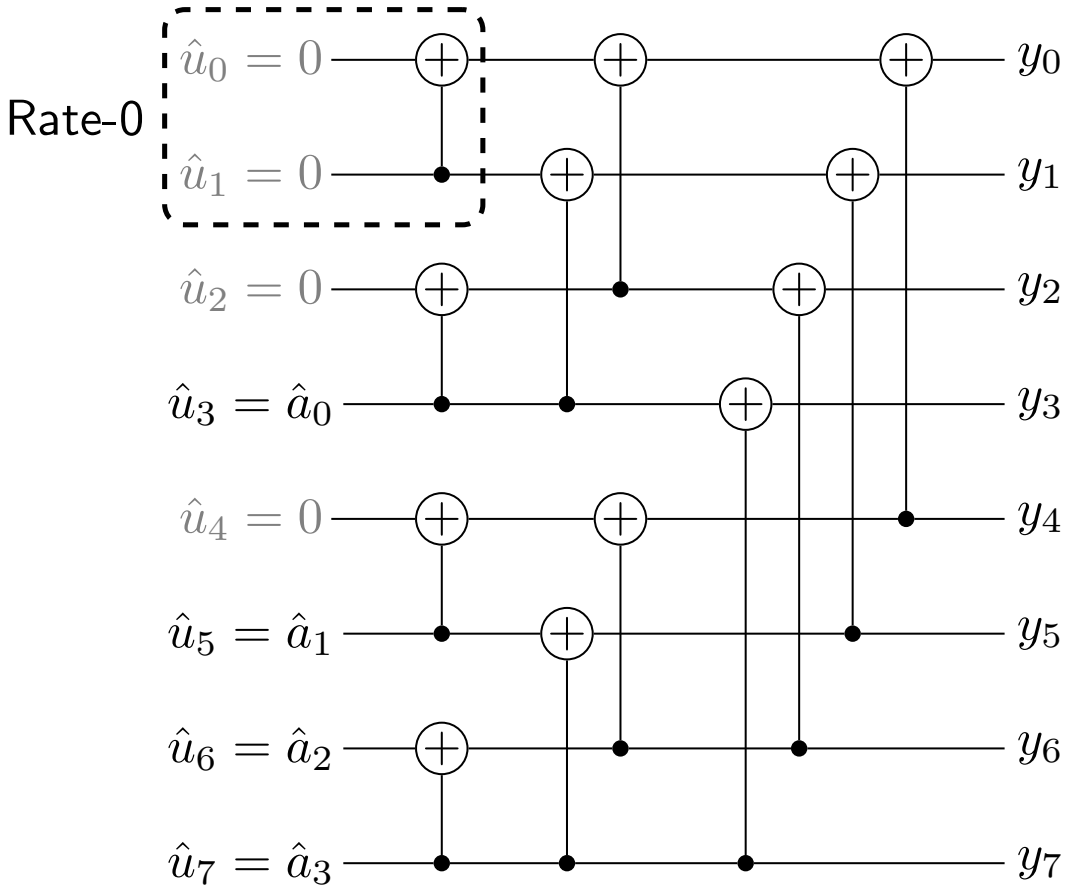

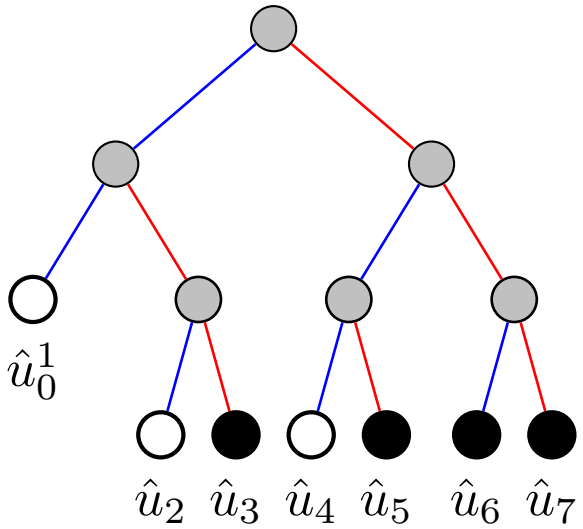

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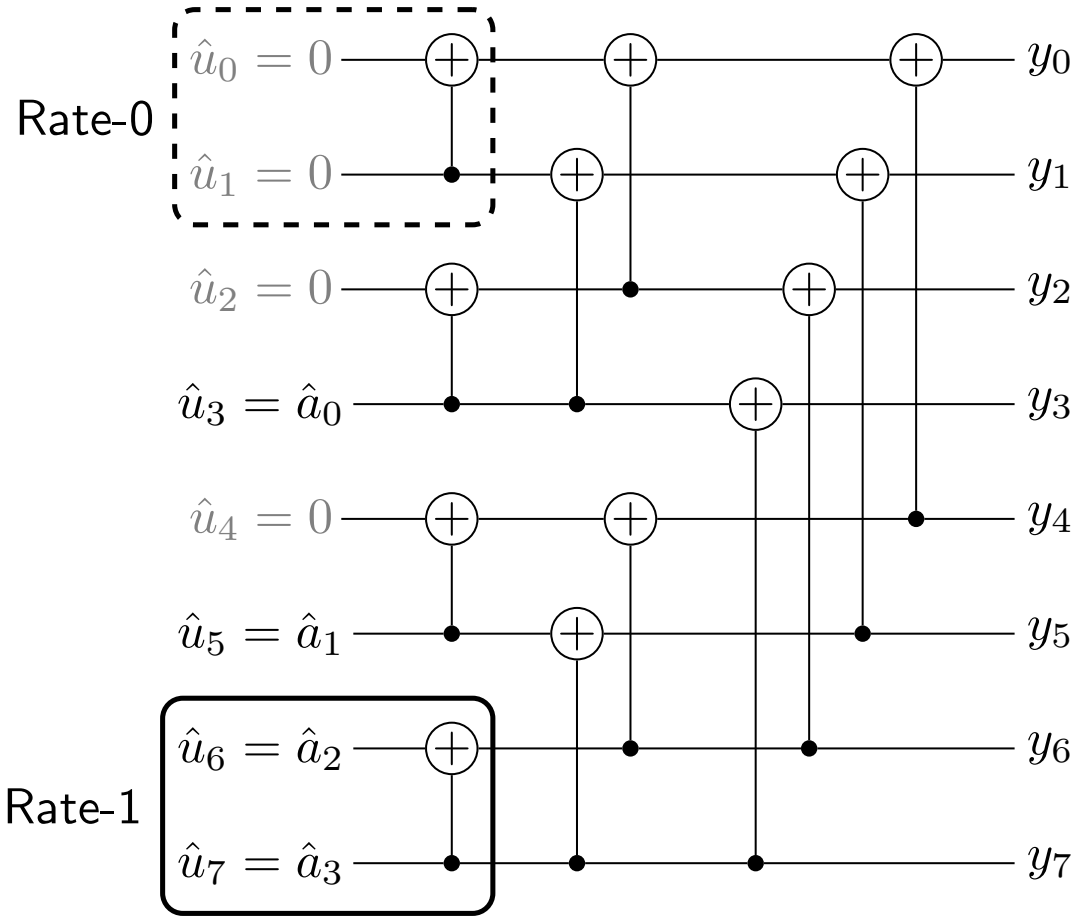

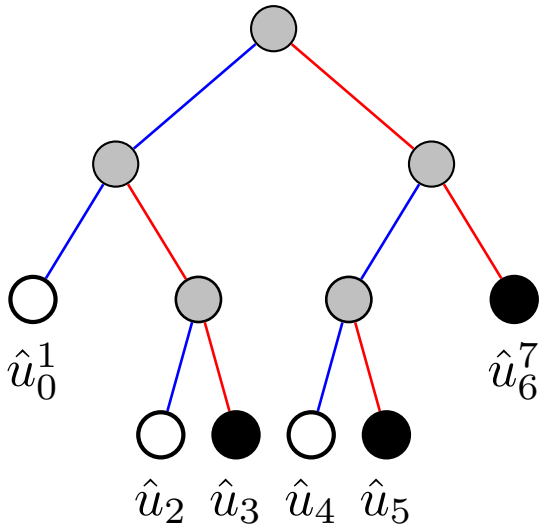

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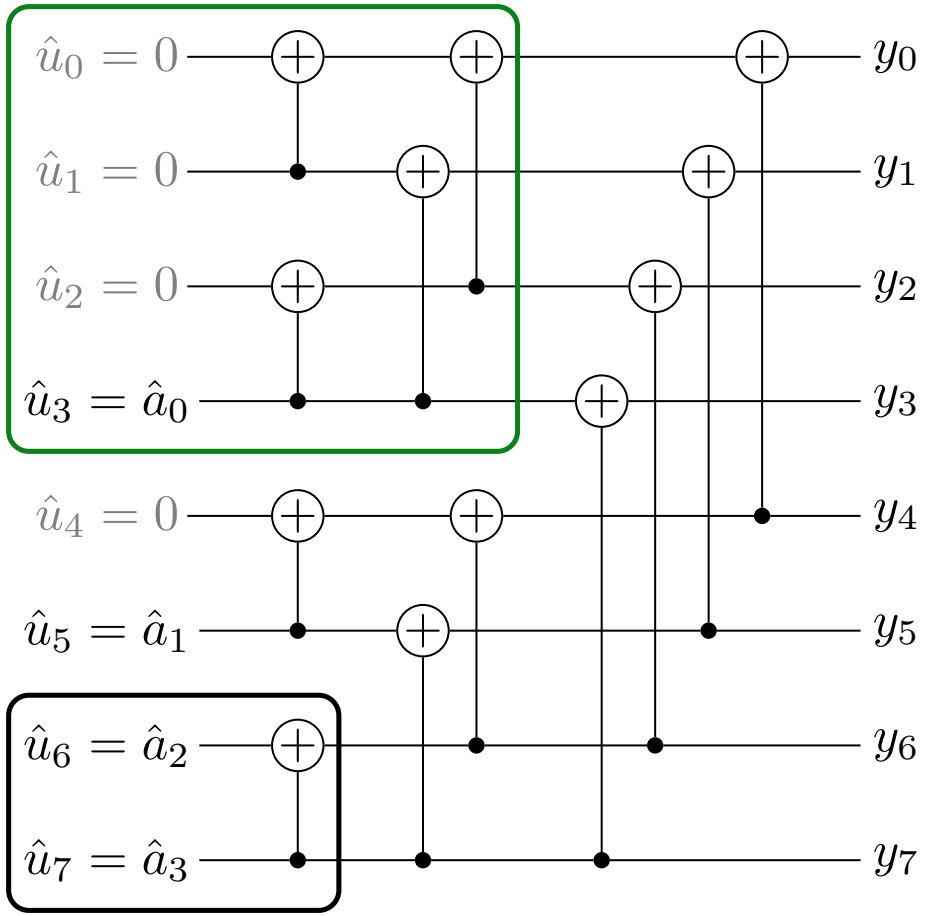

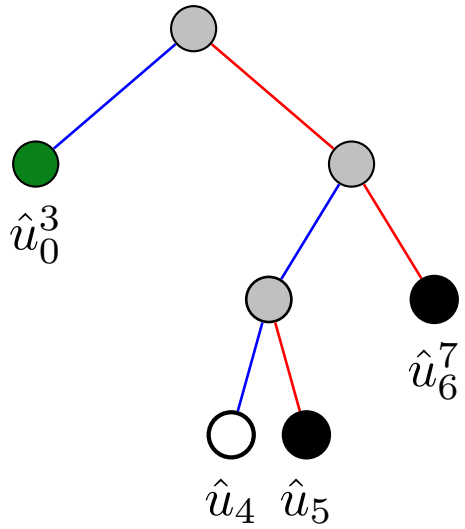

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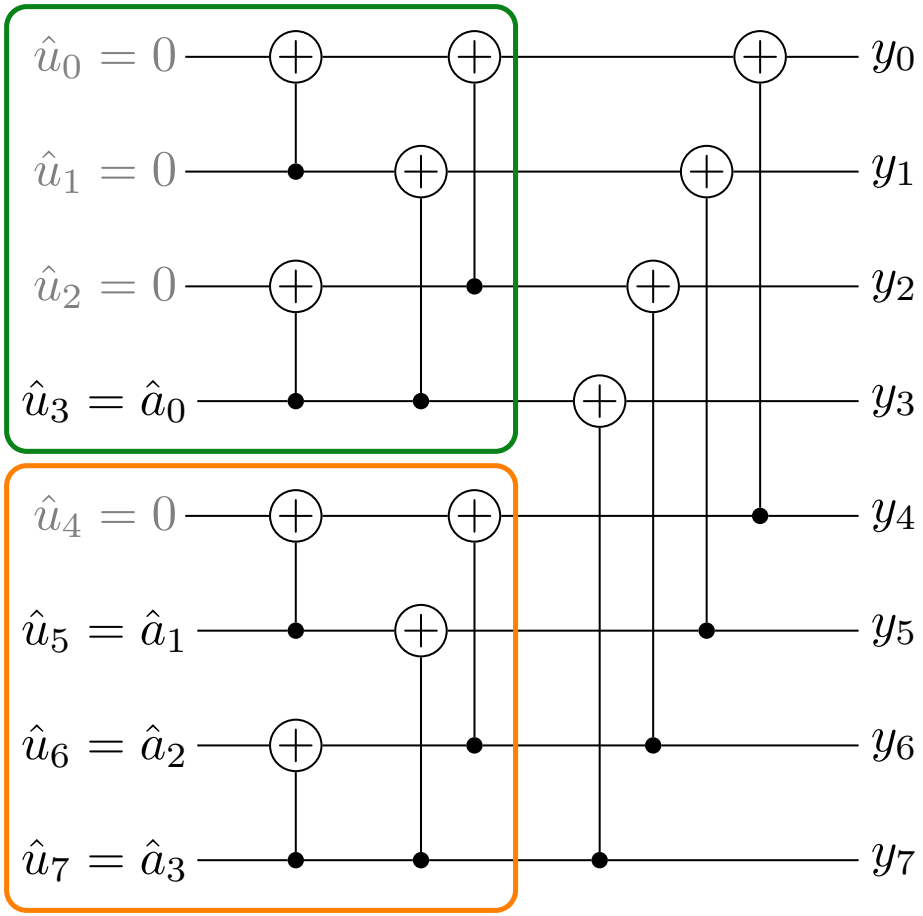

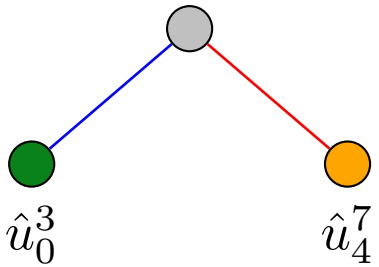

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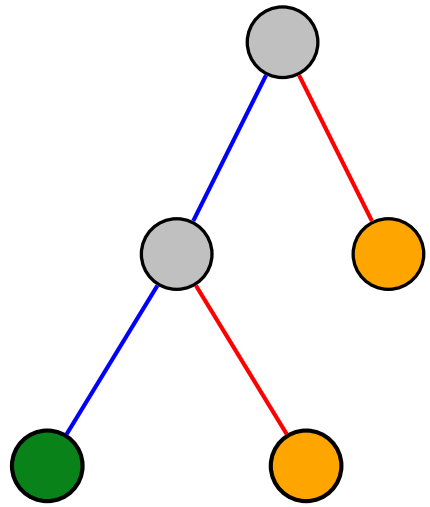
Proposed Blind-Detection Method

Detection Metric

- Exploit the inherent structure of three constituent-code types to compute a detection metric
- The bigger the value of the detection metric, the more likely a received block is encoded with the expected polar code
- Use the detection metric to determine which blocks are forwarded to the next stage, i.e., the more complex decoder



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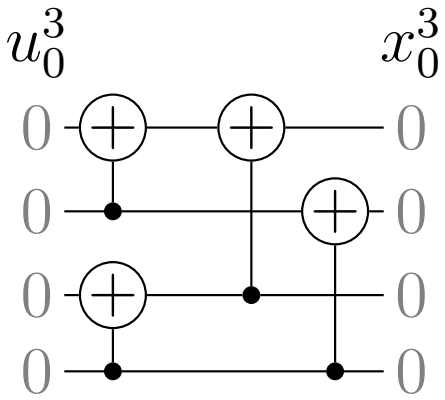
3. Pass on a subset of the best candidates to a more complex SCL decoder

Update Rules – Rate-0 "Code"

- Estimated bit vector $\hat{u}$ known *a priori* to be solely made of frozen bits, i.e., to be an all-zero vector



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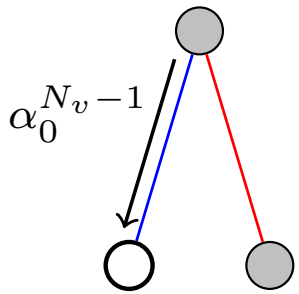

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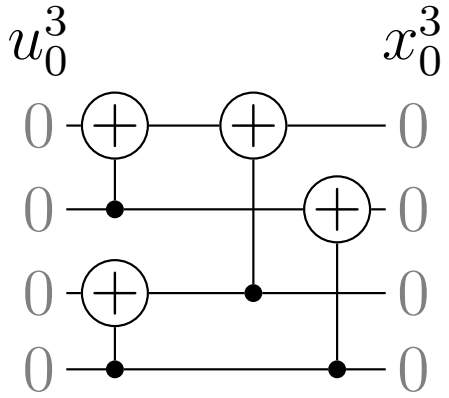

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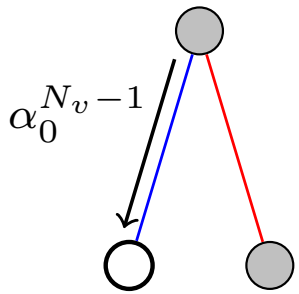

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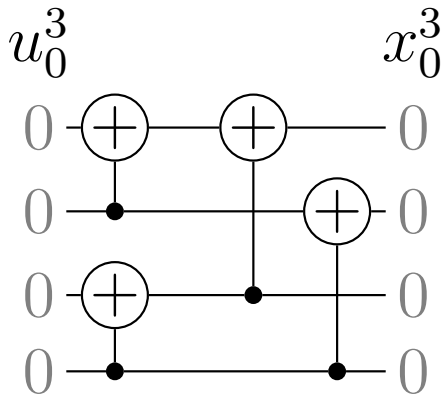

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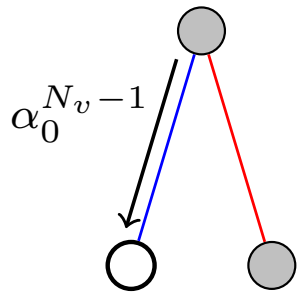

- Scaling factor to normalize w.r.t. to constituent code length

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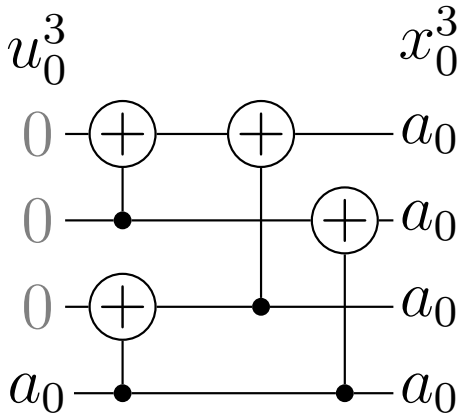

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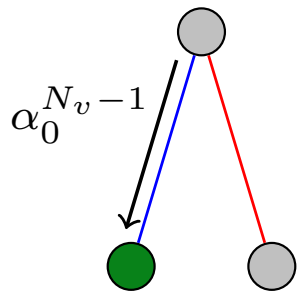

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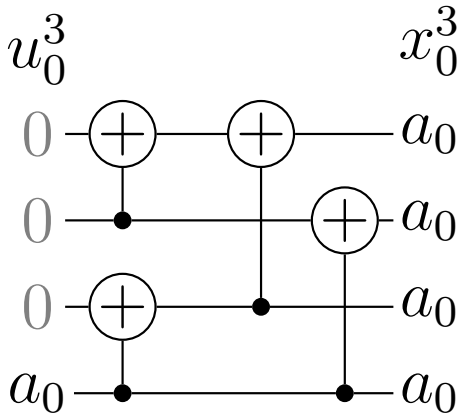

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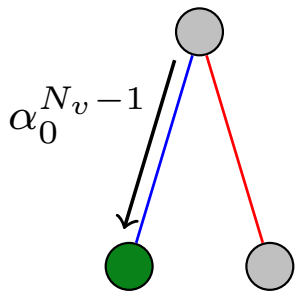

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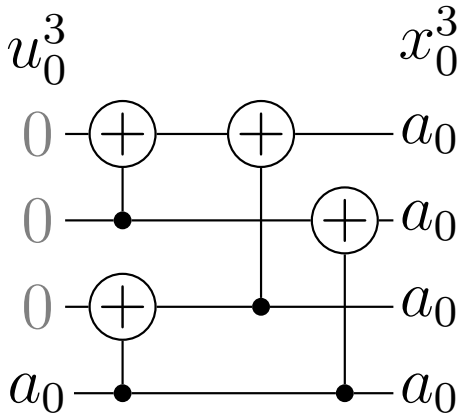

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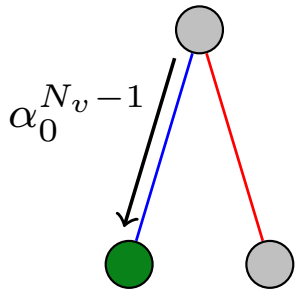

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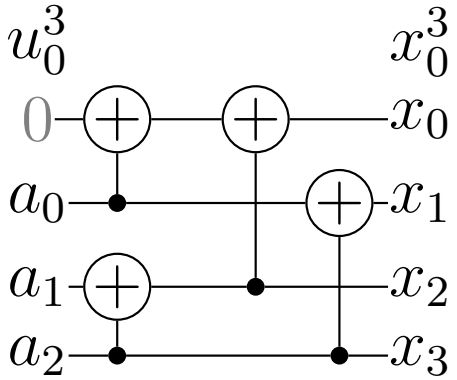

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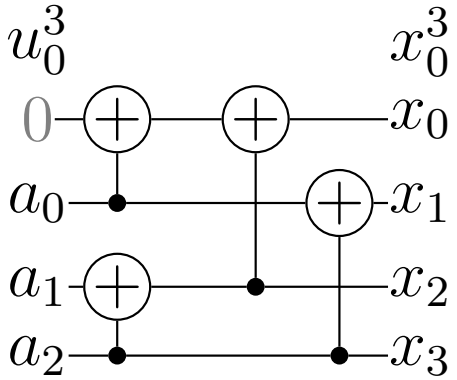

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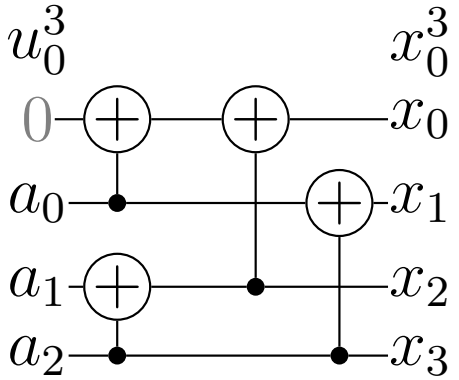

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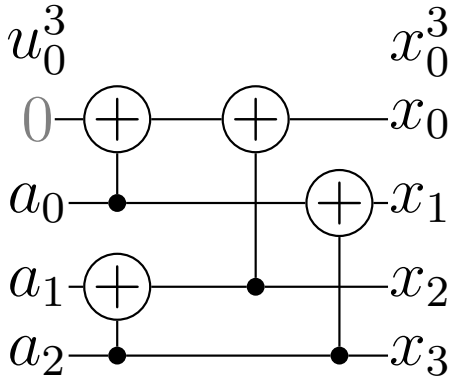
  $\Rightarrow$ Use the least-reliable soft-input LLR to update the detection metric



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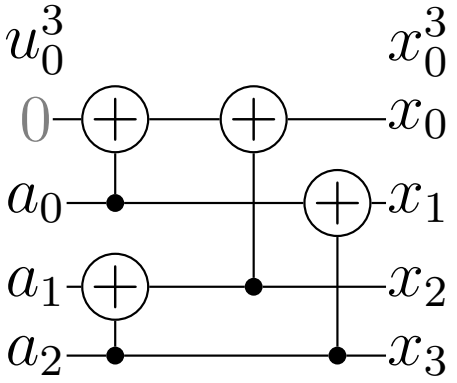
  $\Rightarrow$ Use the least-reliable soft-input LLR to update the detection metric



$$\boldsymbol{x} = \begin{bmatrix} a_0 + a_1 + a_2 \\ a_0 + a_2 \\ a_1 + a_2 \\ a_2 \end{bmatrix}^T$$

$$\boldsymbol{x}' = \begin{bmatrix} a_0 + a_1 + a_2 \\ a_0 \\ a_1 \\ a_2 \end{bmatrix}^T$$

$$\mathcal{D}_t = \mathcal{D}_{t-1} + (-1)^p \min\left(\left|\alpha_0^{N_v-1}\right|\right)$$

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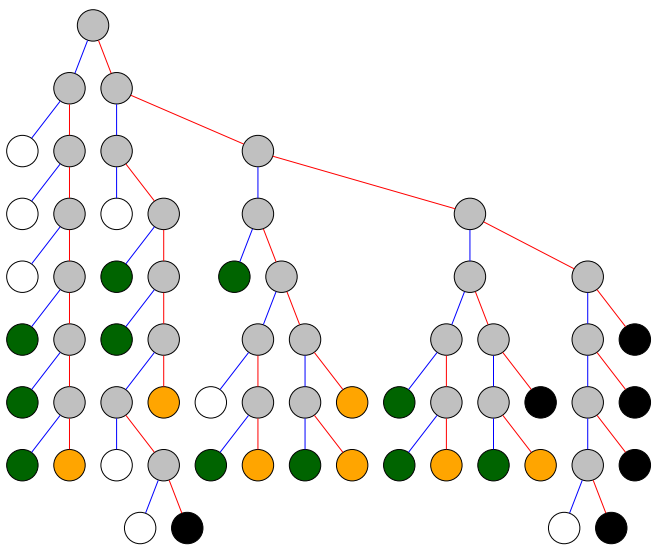

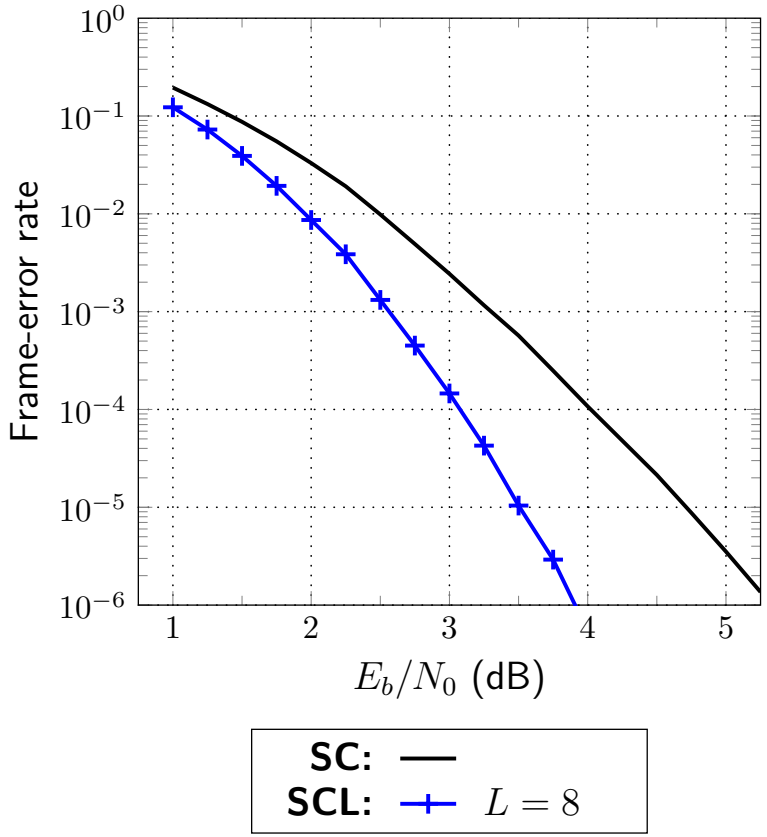

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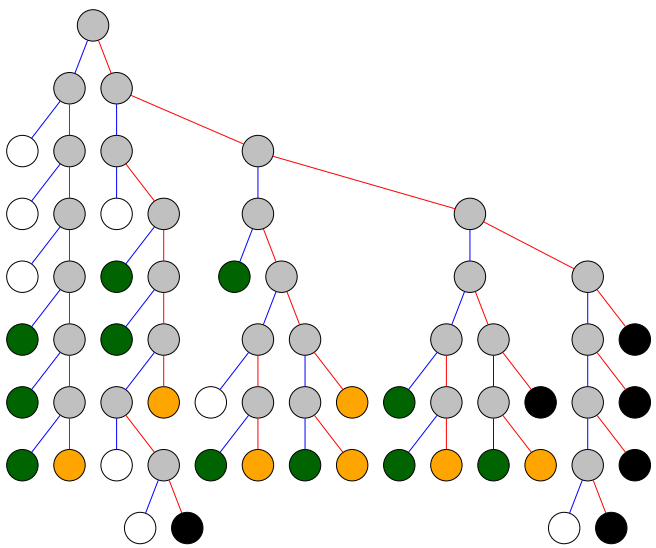
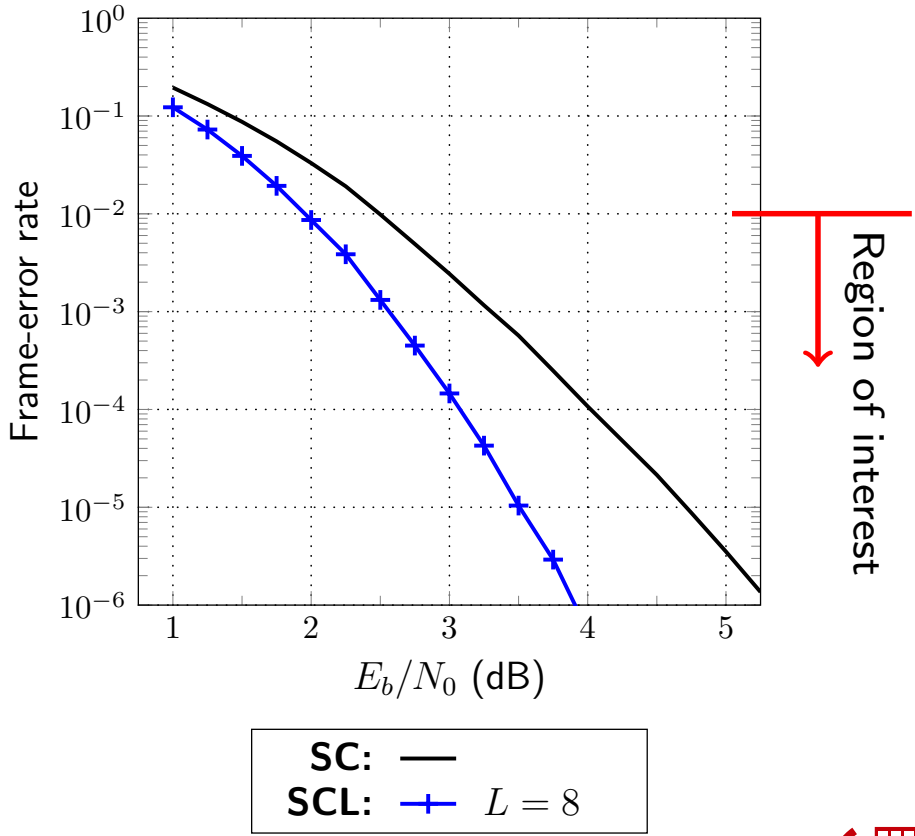
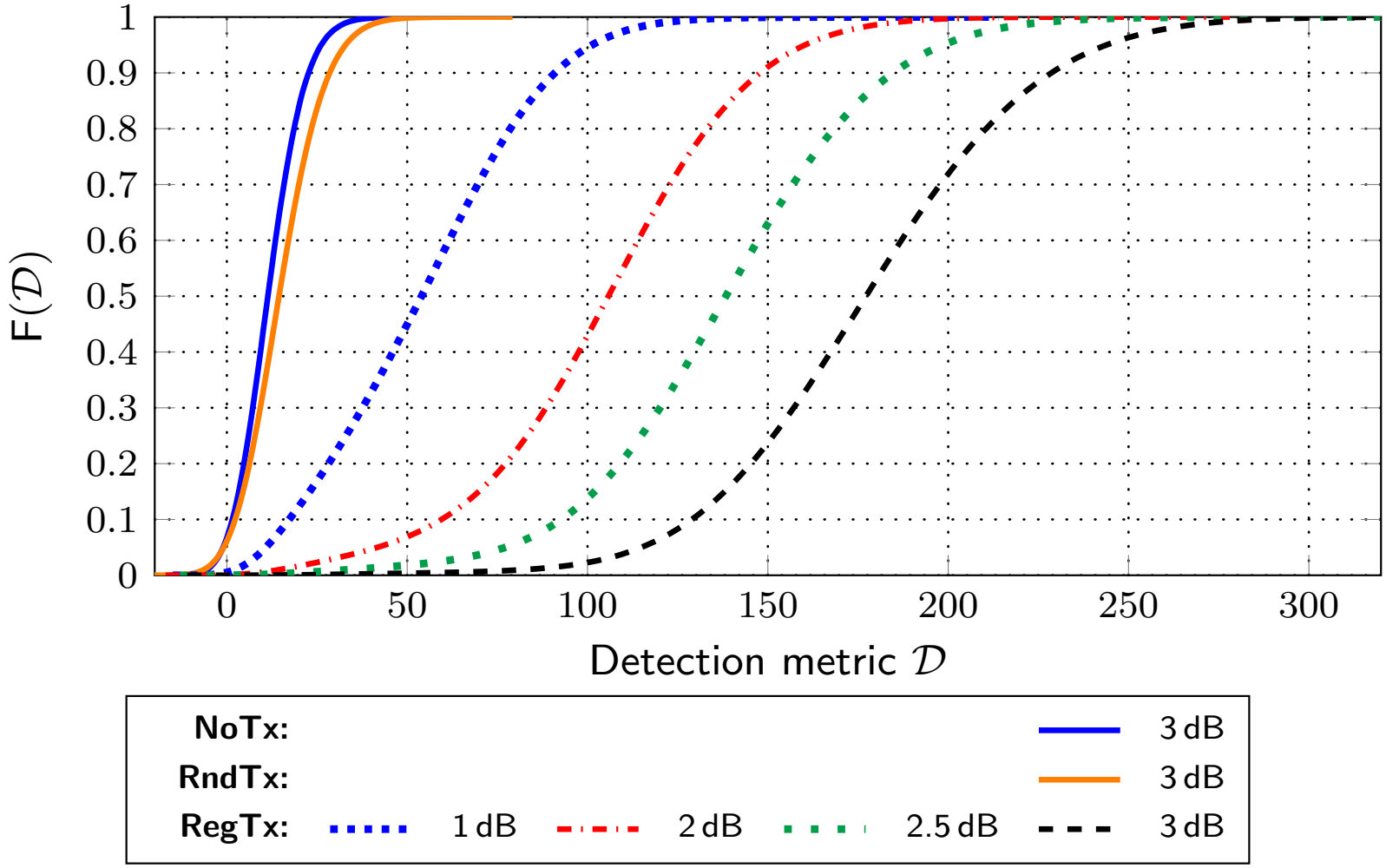




Evaluation of the Proposed Detection Metric

Experimental CDFs of the detection metric



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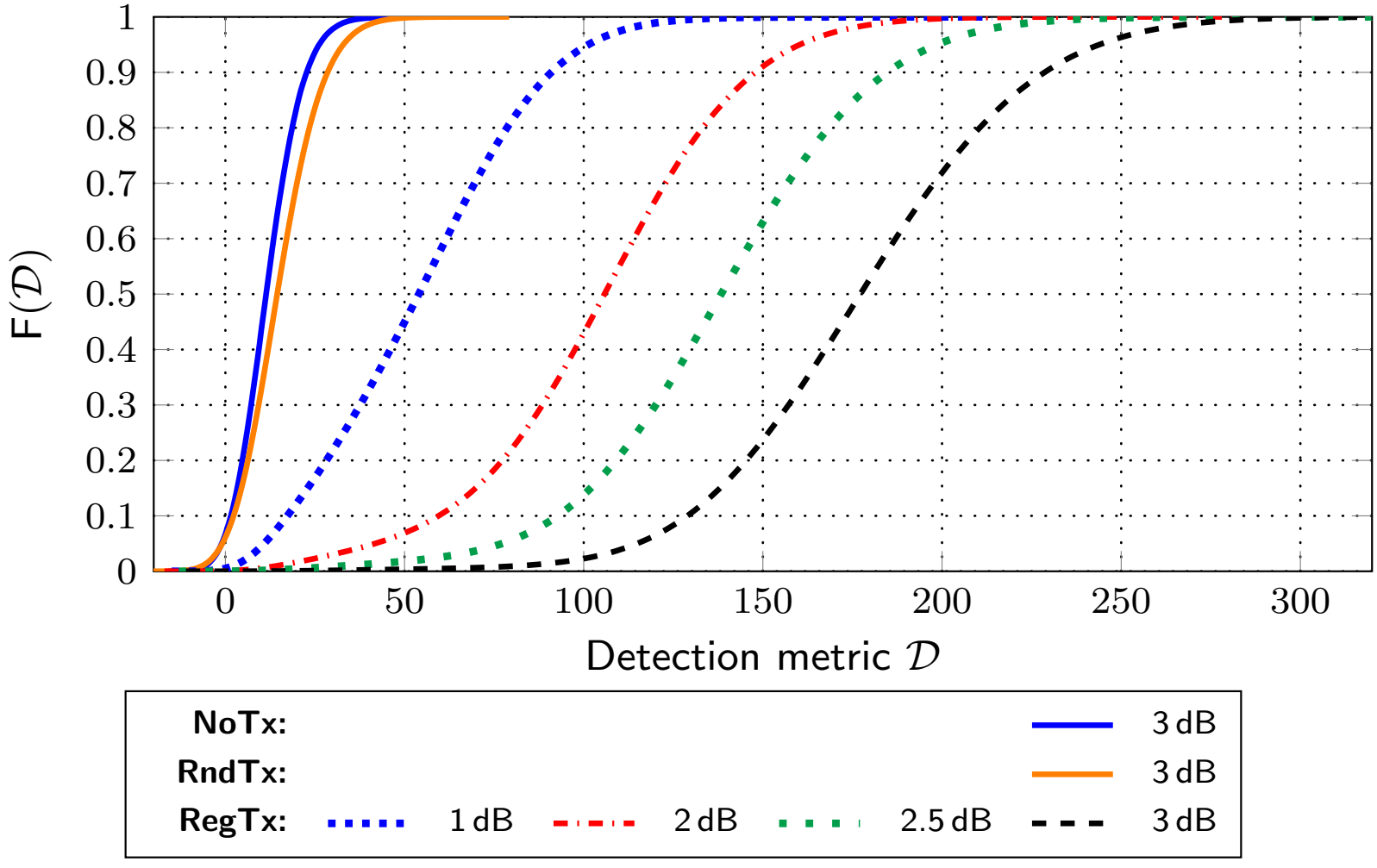
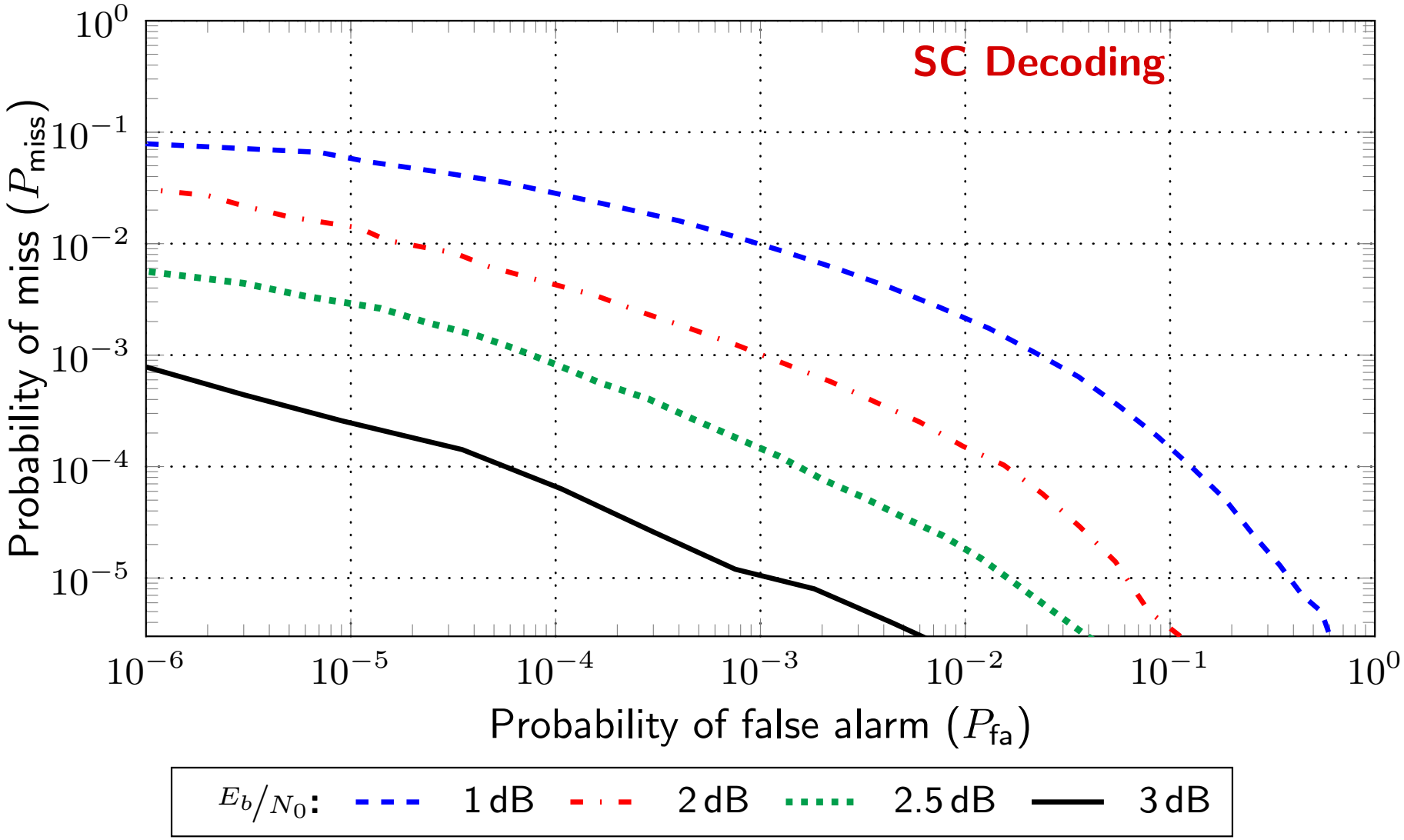


Metric starts to be really good at 2 dB, the region of interest!

Evaluation of the Proposed Detection Metric

Miss rate and false-alarm rate: $P_{\text{miss}} \triangleq \Pr(\mathcal{D} < d \,|\, \mathcal{F}_1)$, $P_{\text{fa}} \triangleq \Pr(\mathcal{D} \geq d \,|\, \mathcal{F}_0)$



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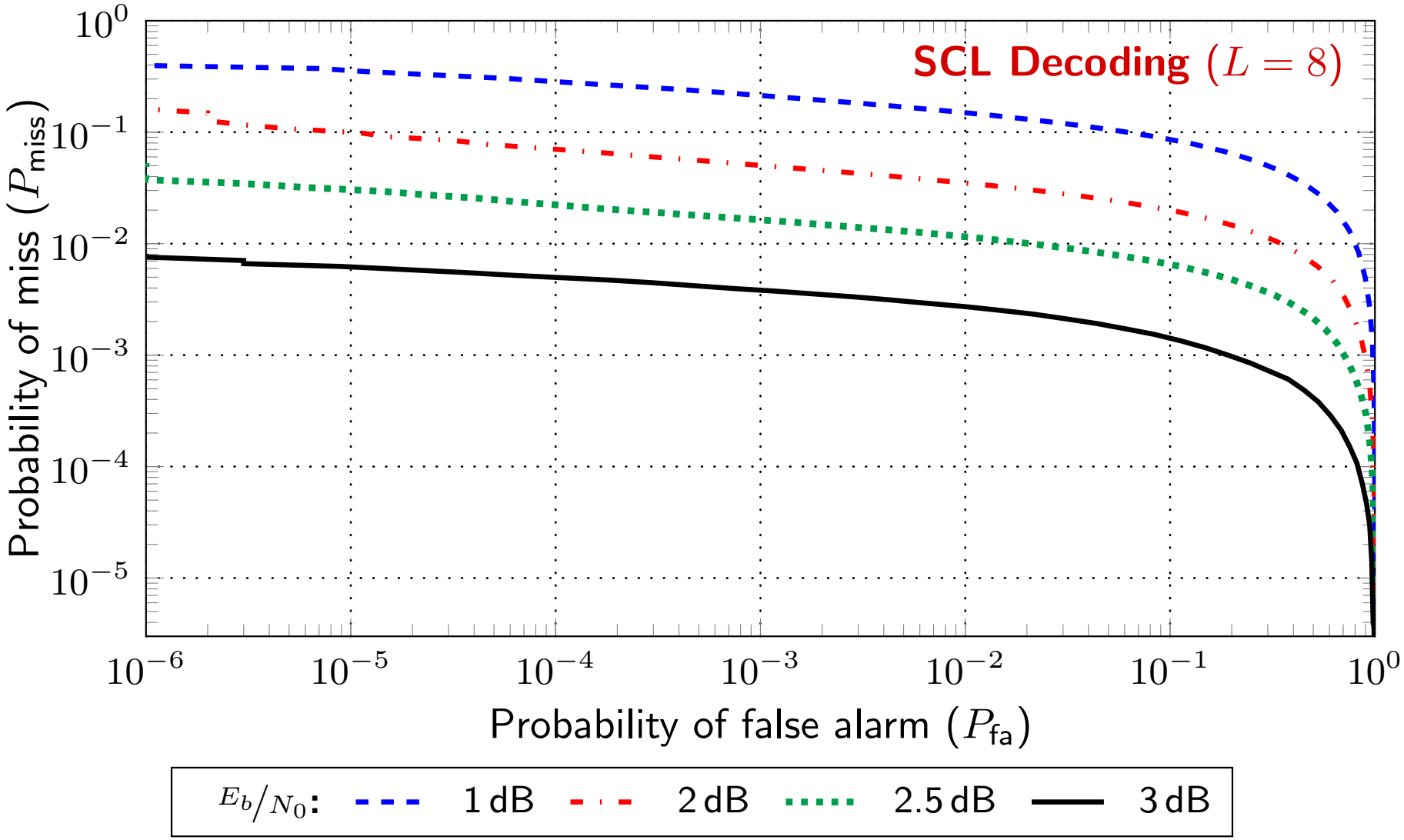

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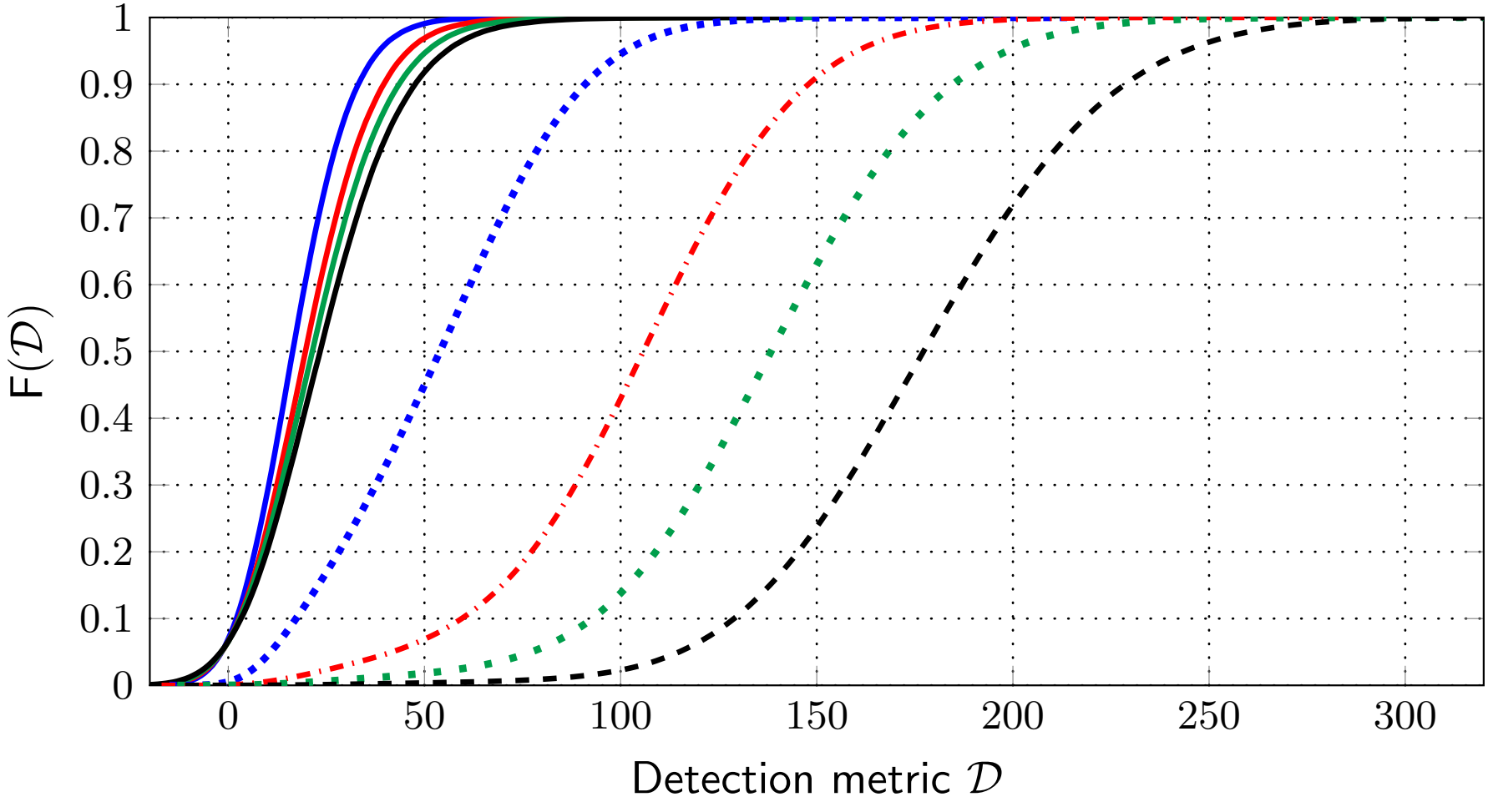
Thank you for listening!

Bonus Slides

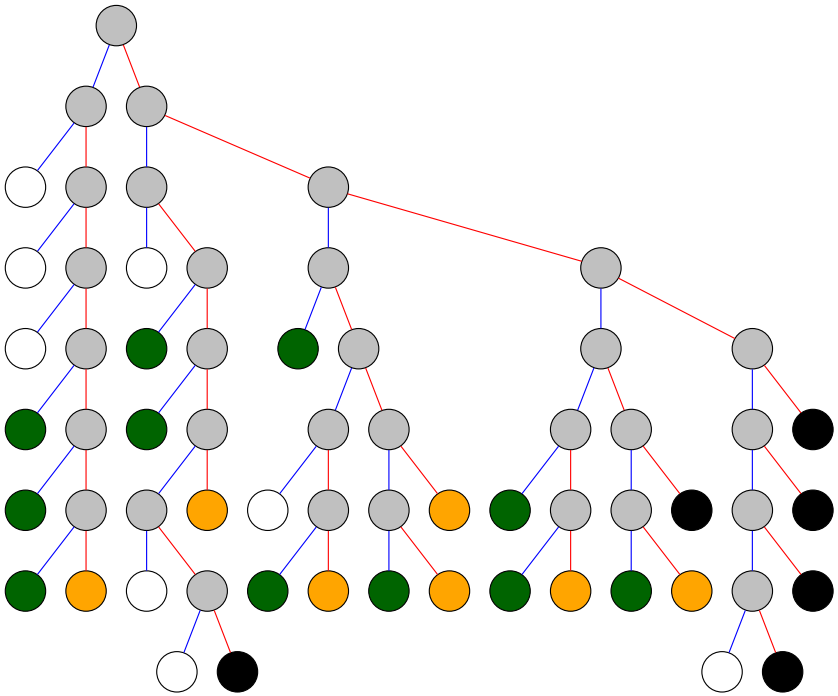
Correlated Input – Different Rate

Experimental CDFs of $\mathcal{D}$; detecting for $R = 1/8$

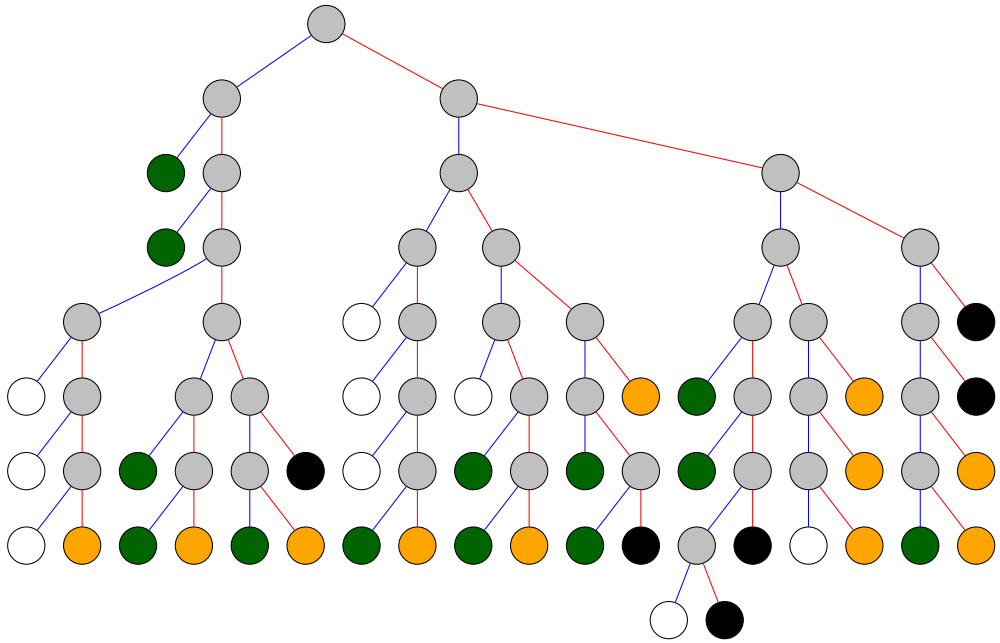


Different Rate – Different Decoder Tree

$R = 1/8$

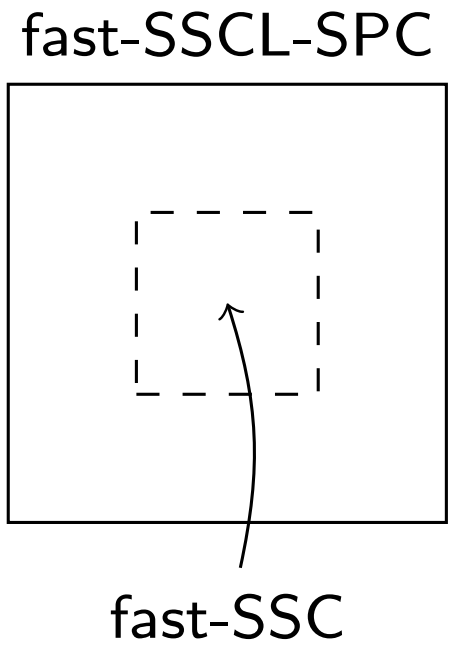


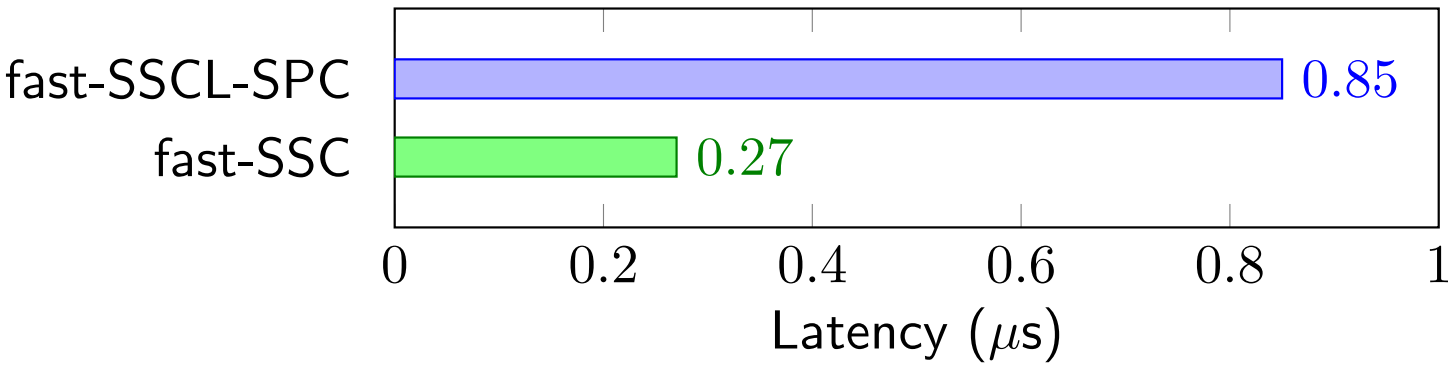
$R = 1/4$



Complexity of the Detector

- **Worst case** time and area complexities approach that of a fast-SSC decoder
- May not be necessary to run the detector on the complete decoder tree
- Area complexity of a fast-SSC decoder is much lower than that of an SCL decoder for $L = 8$





Hashemi, Condo, and Gross., "Fast and Flexible Successive-Cancellation List Decoders for Polar Codes," IEEE TSP, 2017.
Giard, Balatsoukas-Stimming, Sarkis, Thibeault, and Gross., "Fast Low-Complexity Decoders for Low-Rate Polar Codes," Springer JSPS, 2016.