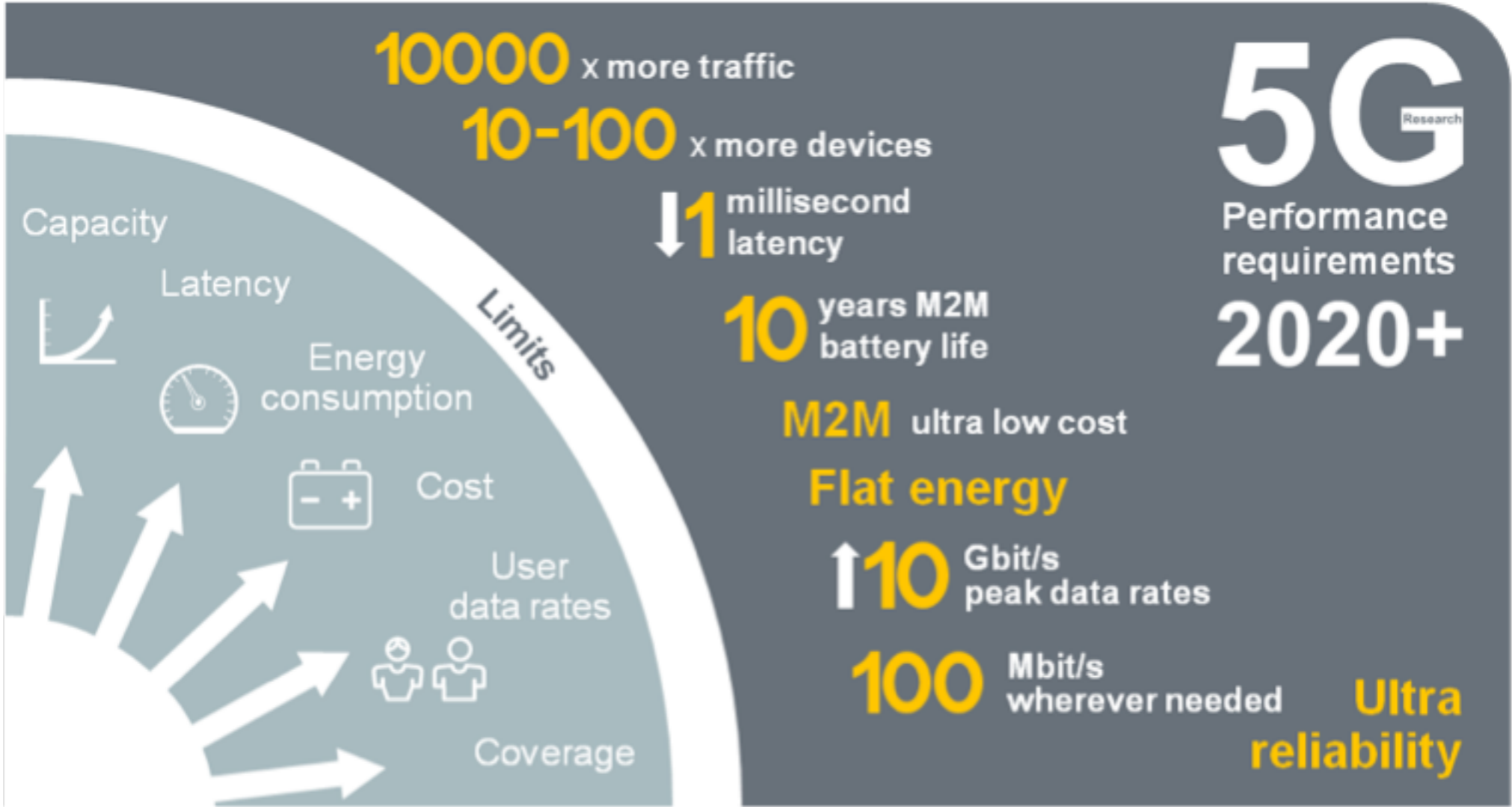


Advances in Error Control Strategies for 5G

Jörg Kliewer

The Elisha Yegal Bar-Ness Center For Wireless
Communications And Signal Processing Research

5G Requirements



[Nokia Networks: Looking ahead to 5G. White paper, April 2014]

Energy Bottleneck

- Current computational cost of transmission: approx. 6 nJ/bit
[Andrews et al. 2014]
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Resulting battery life: **5 minutes and 27 seconds!**

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In order to satisfy the **5G requirements**, we need a **paradigm change** in coding.

- 3G/4G coding is essentially **capacity-approaching** for point-to-point BI-AWGN

Coding Wish List for 5G

- 3G/4G coding is essentially **capacity-approaching** for point-to-point BI-AWGN
- **Gains in transmission power efficiency** to be expected from
 - ▶ Coding for **spectrally efficiency** communication
 - ▶ **Multi-terminal coding and decoding** (i.e., for relaying, cooperation, MIMO)

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 - ▶ Coding for **spectrally efficiency** communication
 - ▶ **Multi-terminal coding and decoding** (i.e., for relaying, cooperation, MIMO)
- Gains in **computational power efficiency** equally important

One Code Fits All?



Not Really...



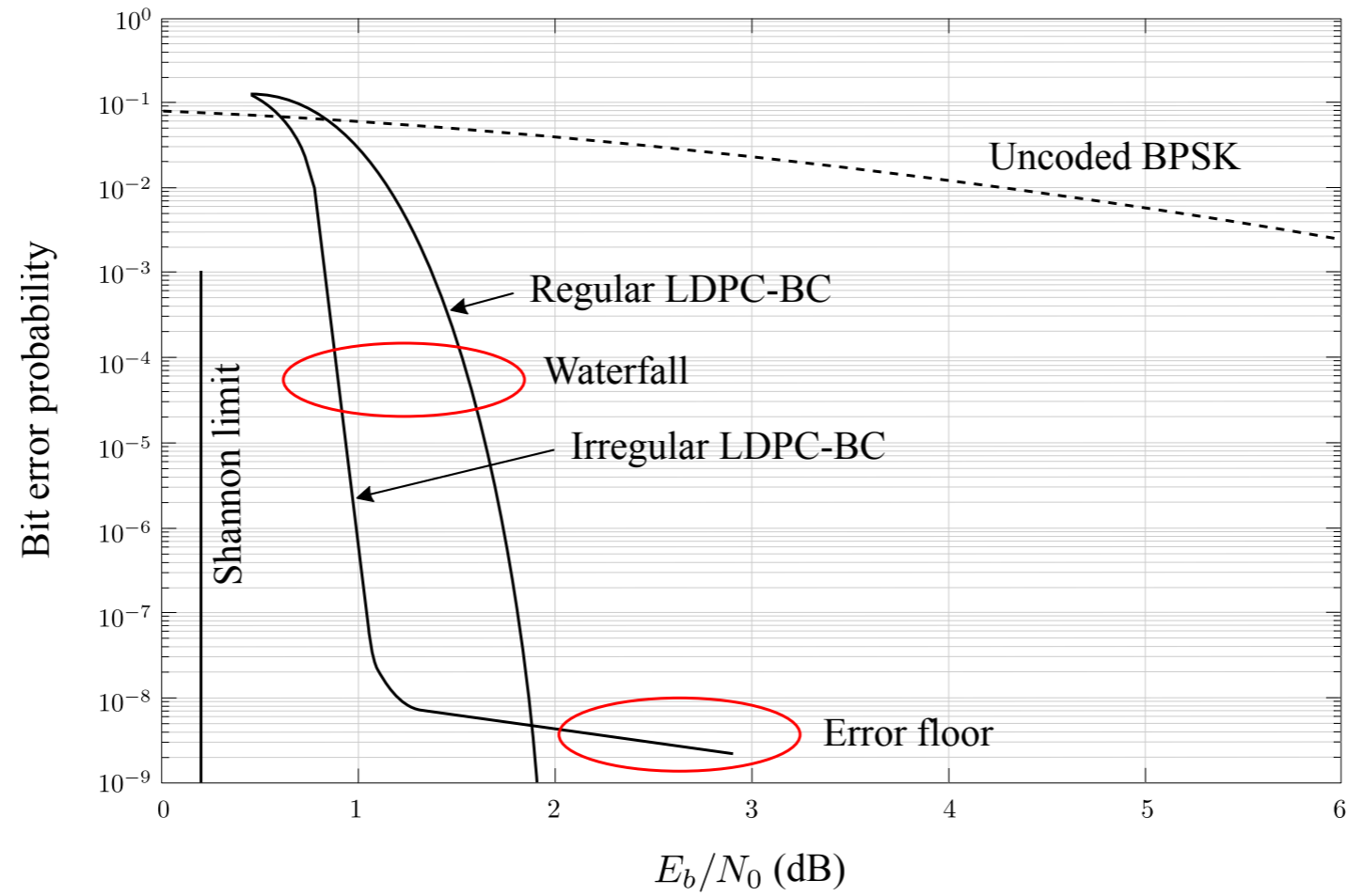
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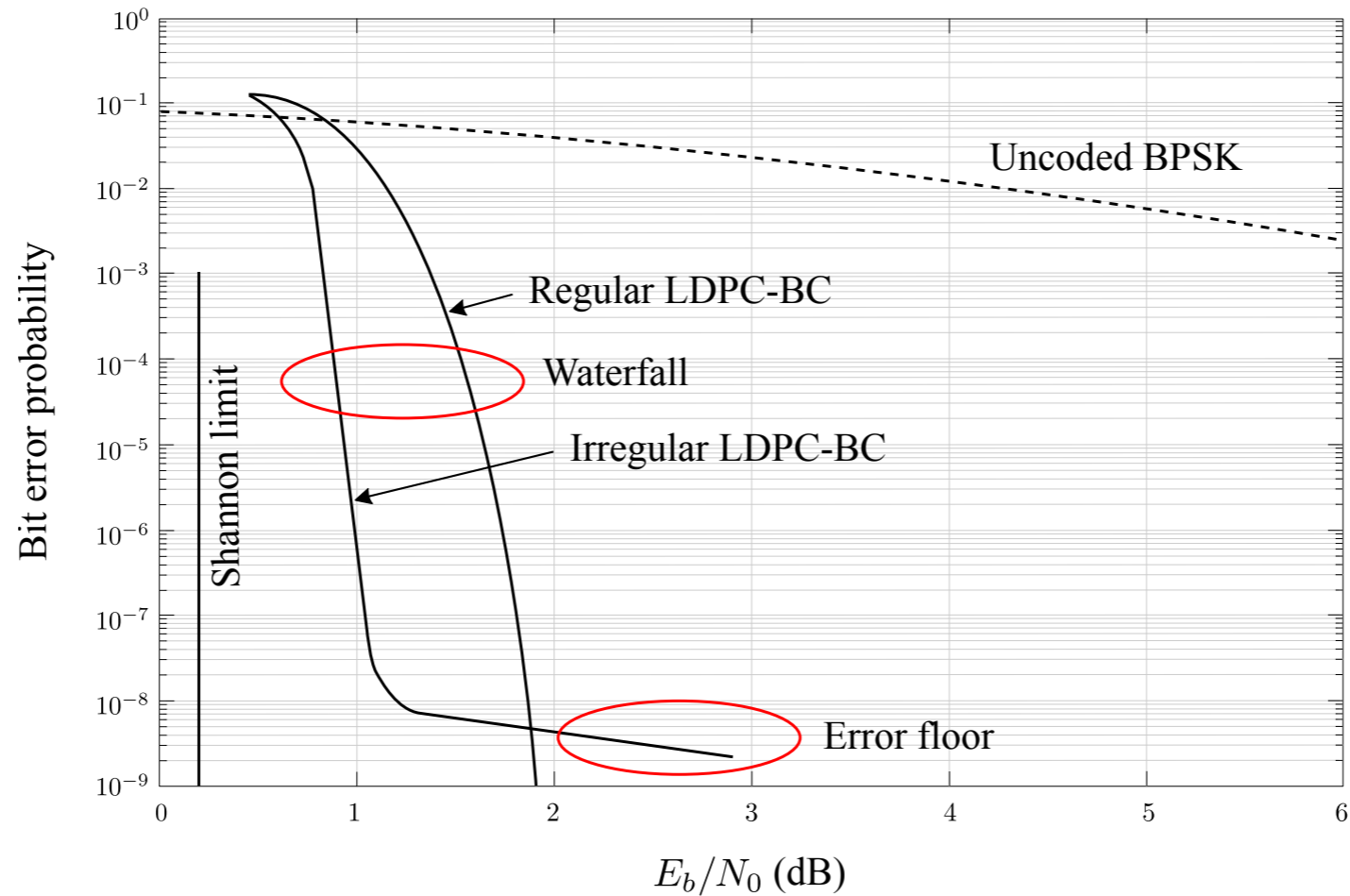
No **single** scheme which fixes all these issues, but few **promising candidates**:

- **Spatially coupled (convolutional) LDPC codes**
- **Non-binary LDPC codes**
- **Polar codes**

LDPC Block Codes

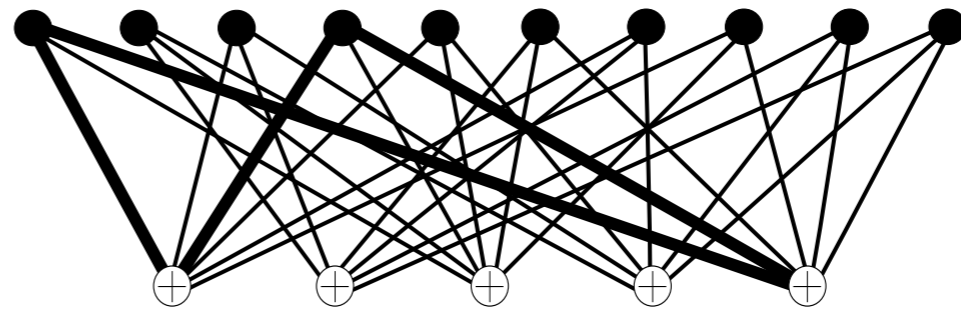


LDPC Block Codes



Tanner graph (3,6) regular LDPC code:

$$\mathbf{H} = \begin{bmatrix} 1 & 0 & 1 & 1 & 1 & 0 & 1 & 1 & 0 & 0 \\ 0 & 1 & 1 & 0 & 0 & 1 & 1 & 0 & 1 & 1 \\ 1 & 1 & 0 & 1 & 1 & 1 & 0 & 1 & 0 & 0 \\ 0 & 1 & 1 & 0 & 1 & 0 & 1 & 0 & 1 & 1 \\ 1 & 0 & 0 & 1 & 0 & 1 & 0 & 1 & 1 & 1 \end{bmatrix}$$



Graph sparsely connected

Spatially Coupled LDPC Codes

- Invented as convolutional LDPC codes [Jiménez-Feltström & Zigangirov 1999], theory [Kudekar, Richardson, Urbanke 2010]
- Asymptotically **universally capacity achieving** for a wide range of channels and code rates

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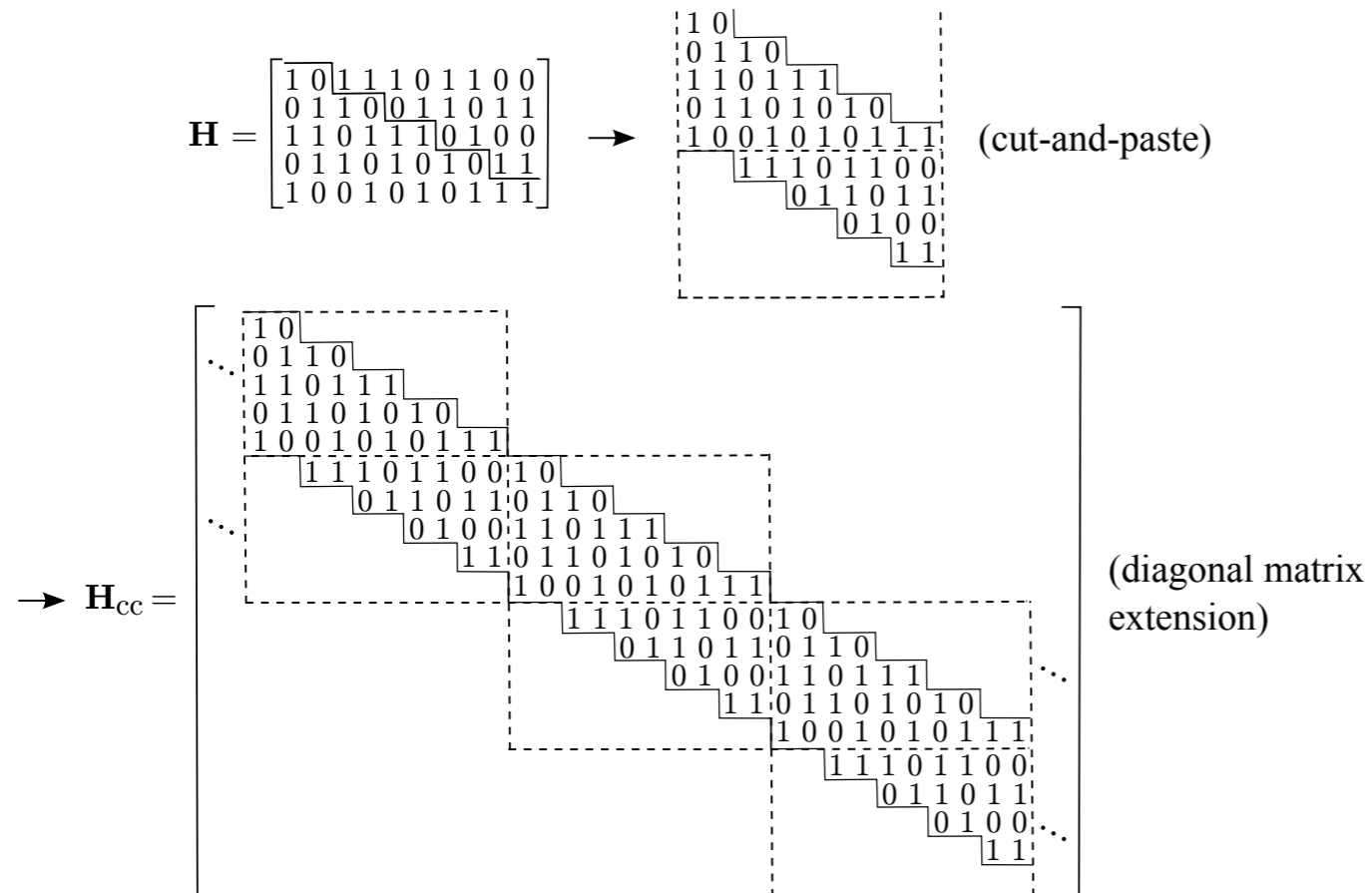
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- Decoding complexity and latency reduction by **windowed decoding**

Spatially Coupled LDPC Codes

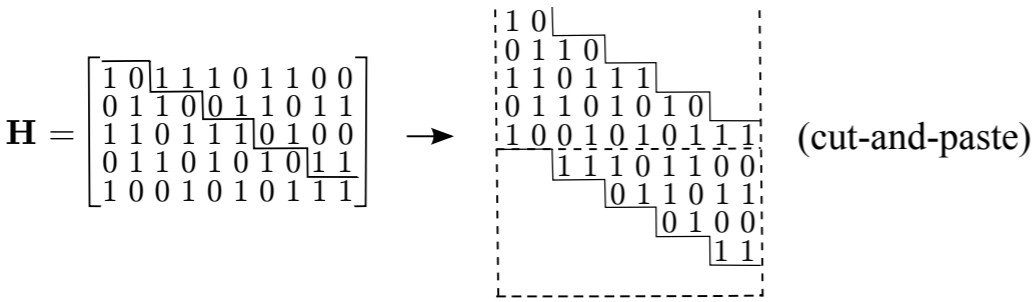
Coupling construction via unwrapping:



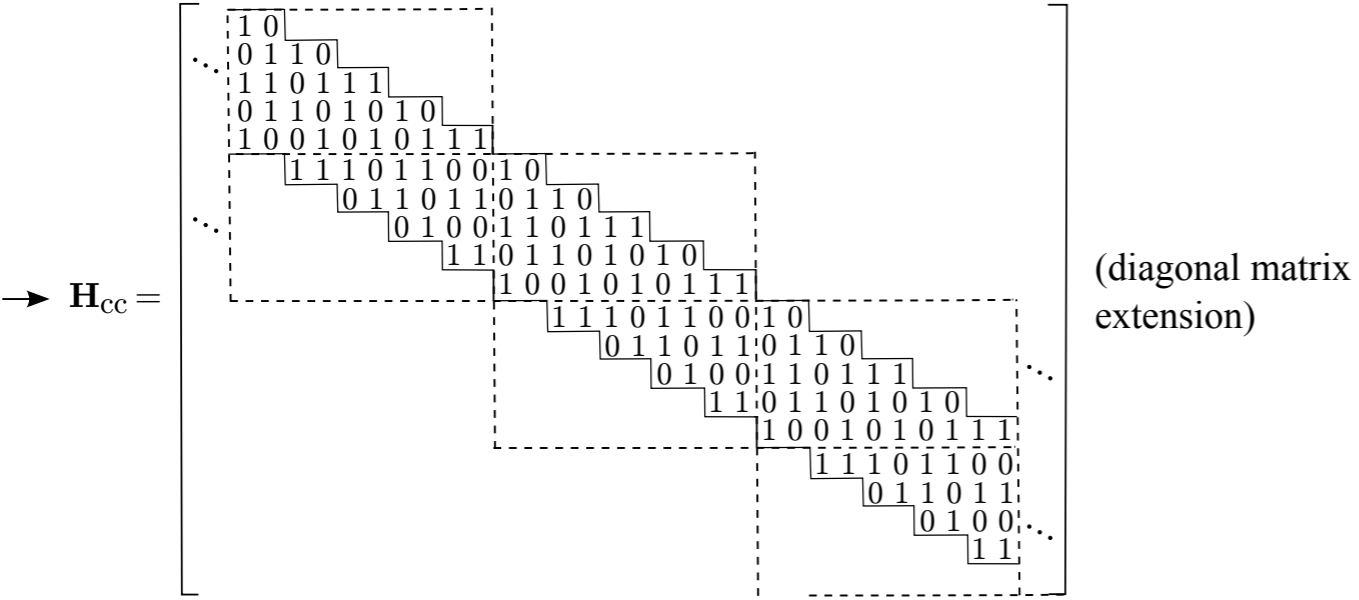
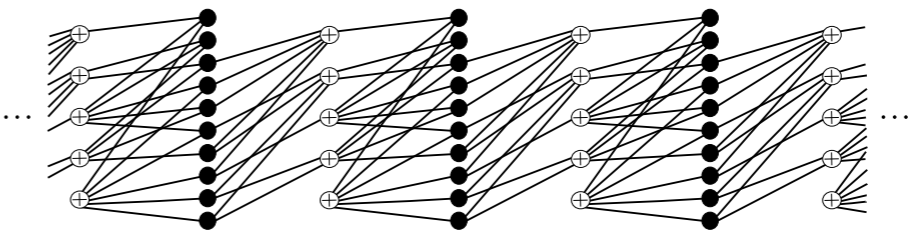
Convolutional code structure

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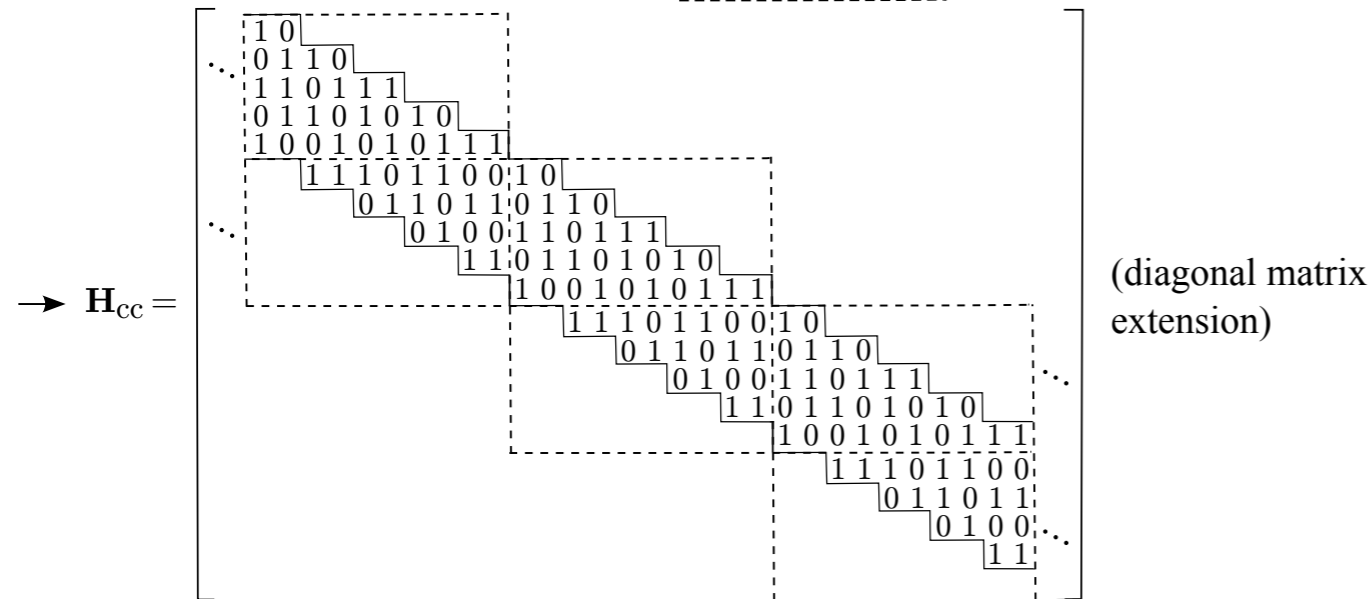
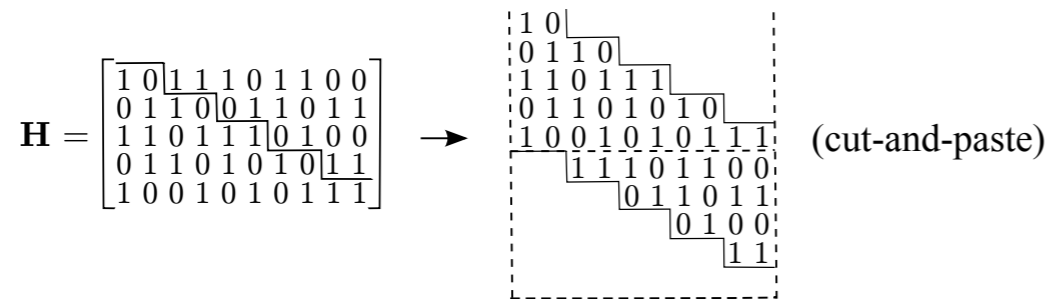
Resulting Tanner graph:



Convolutional code structure

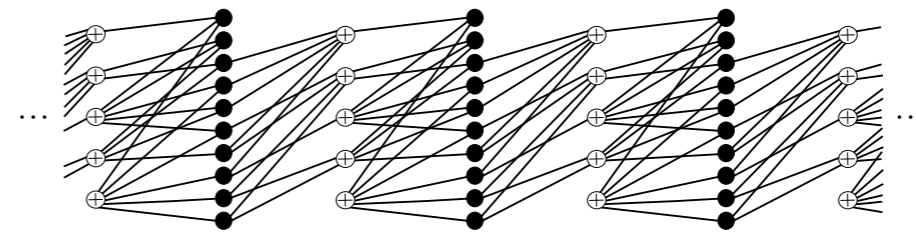
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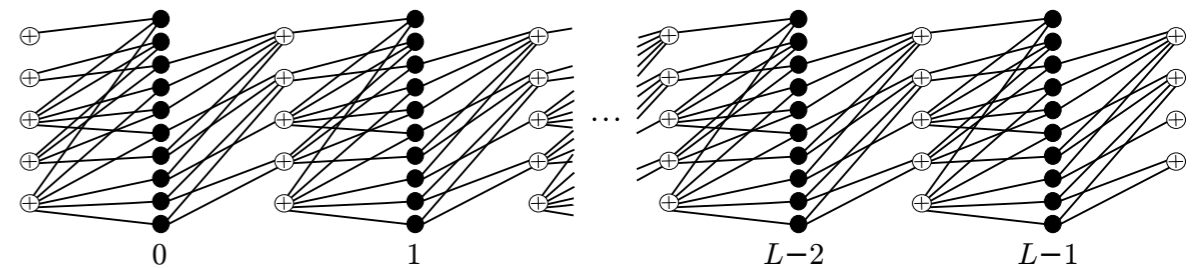


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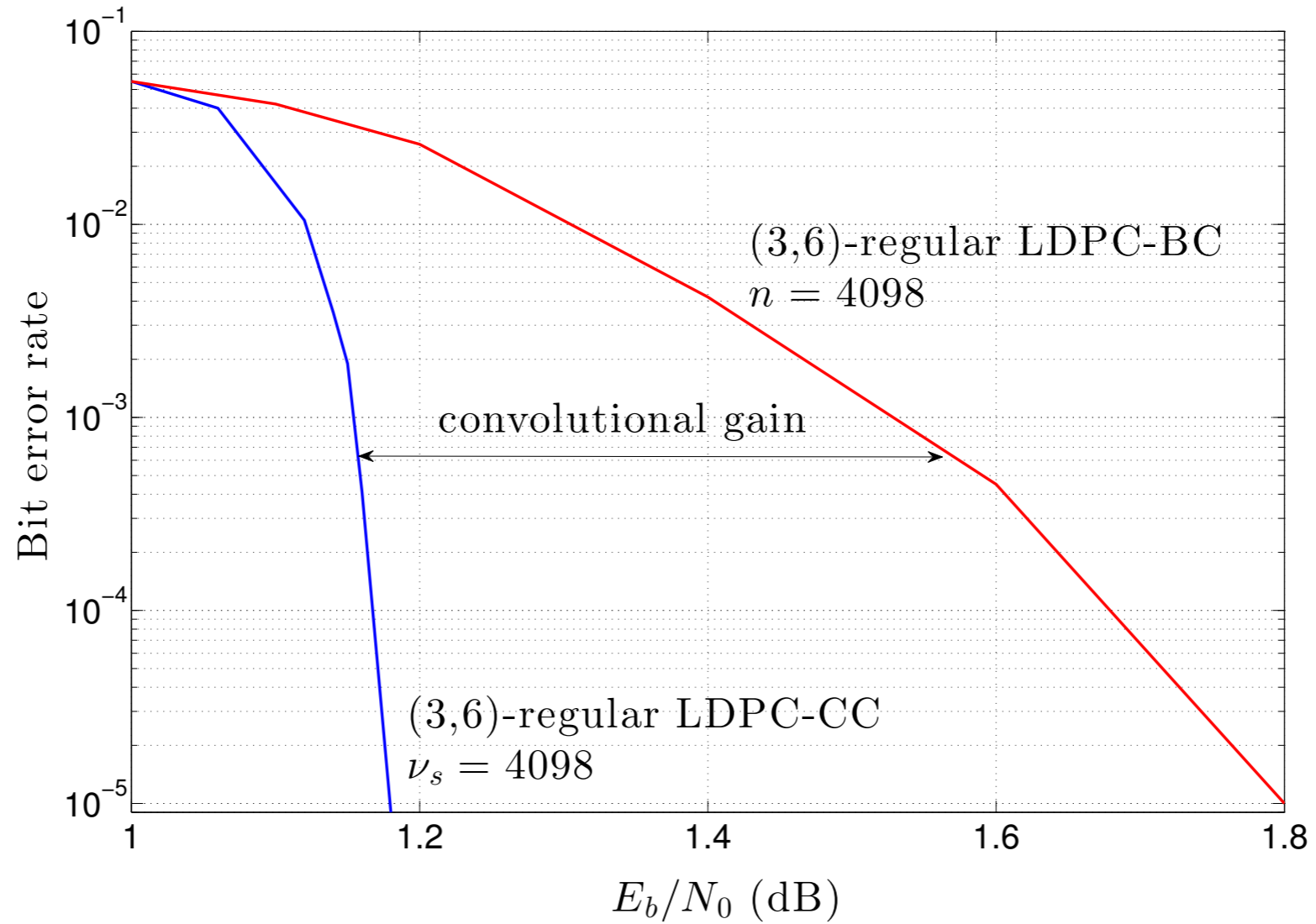
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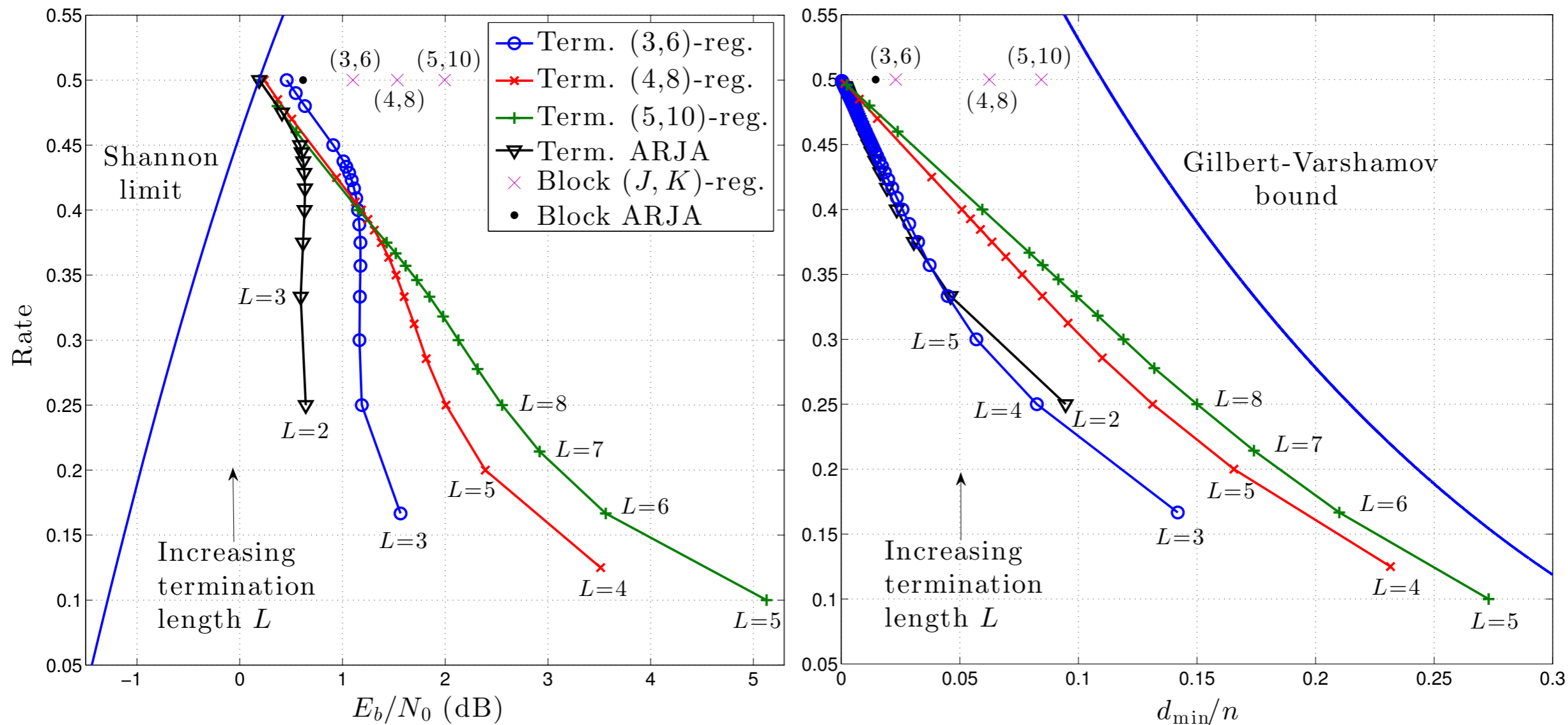
Terminated Tanner graph:



Spatially Coupled LDPC Codes: Performance



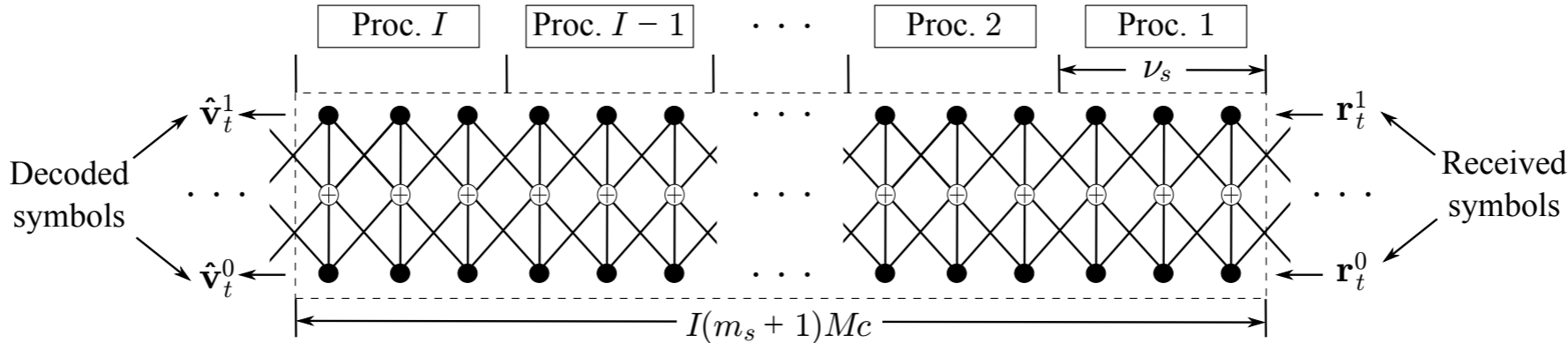
Spatially Coupled LDPC Codes: Performance



[Costello, Dolecek, Fuja, Klierer, Mitchell, Smarandache, 2014]

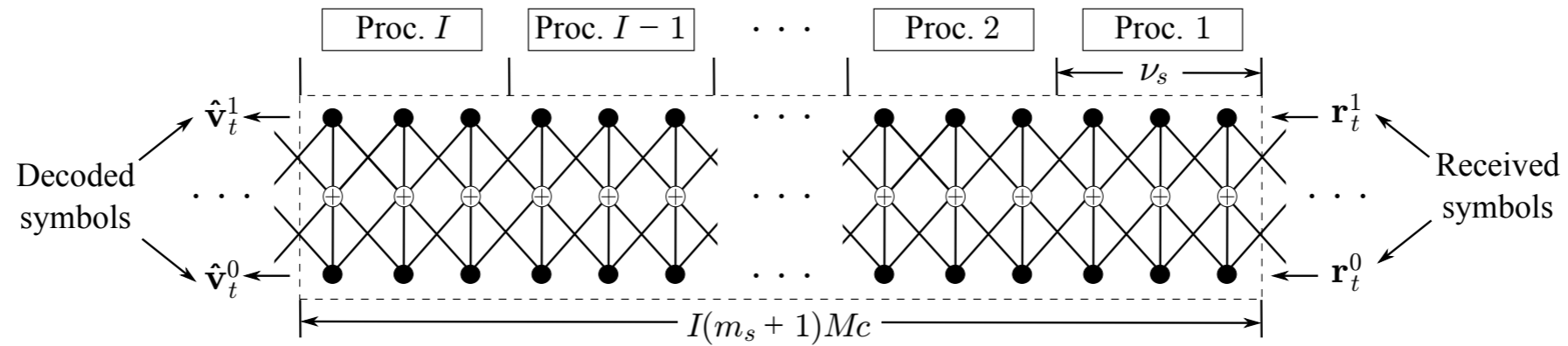
Spatially Coupled LDPC Codes: Efficient Decoding

Pipeline decoding:

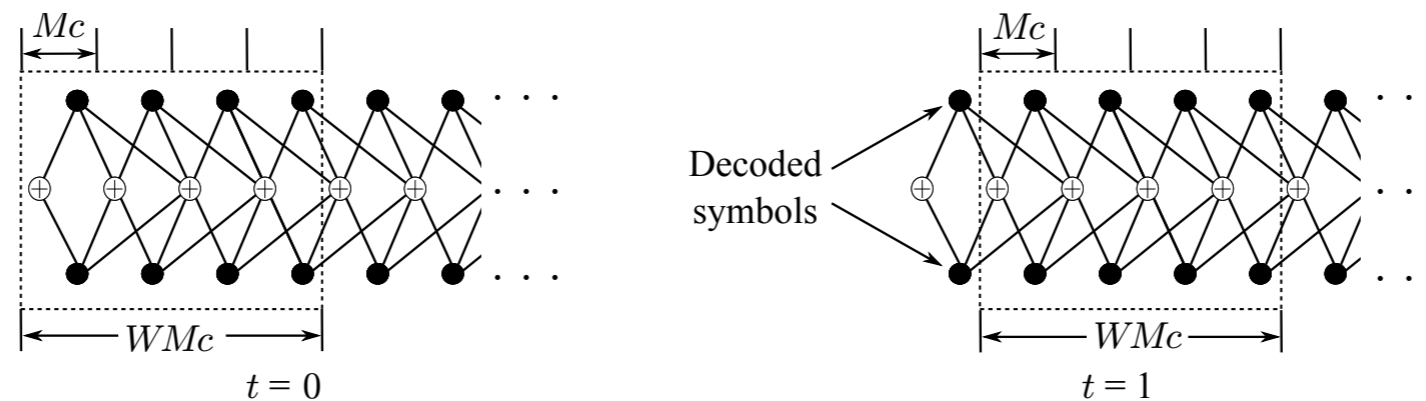


Spatially Coupled LDPC Codes: Efficient Decoding

Pipeline decoding:



Low-latency low-complexity windowed decoding:



Non-Binary LDPC Codes

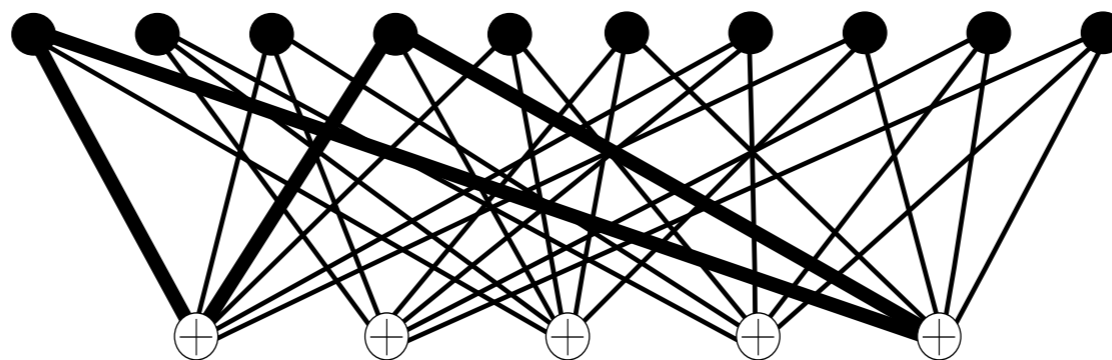
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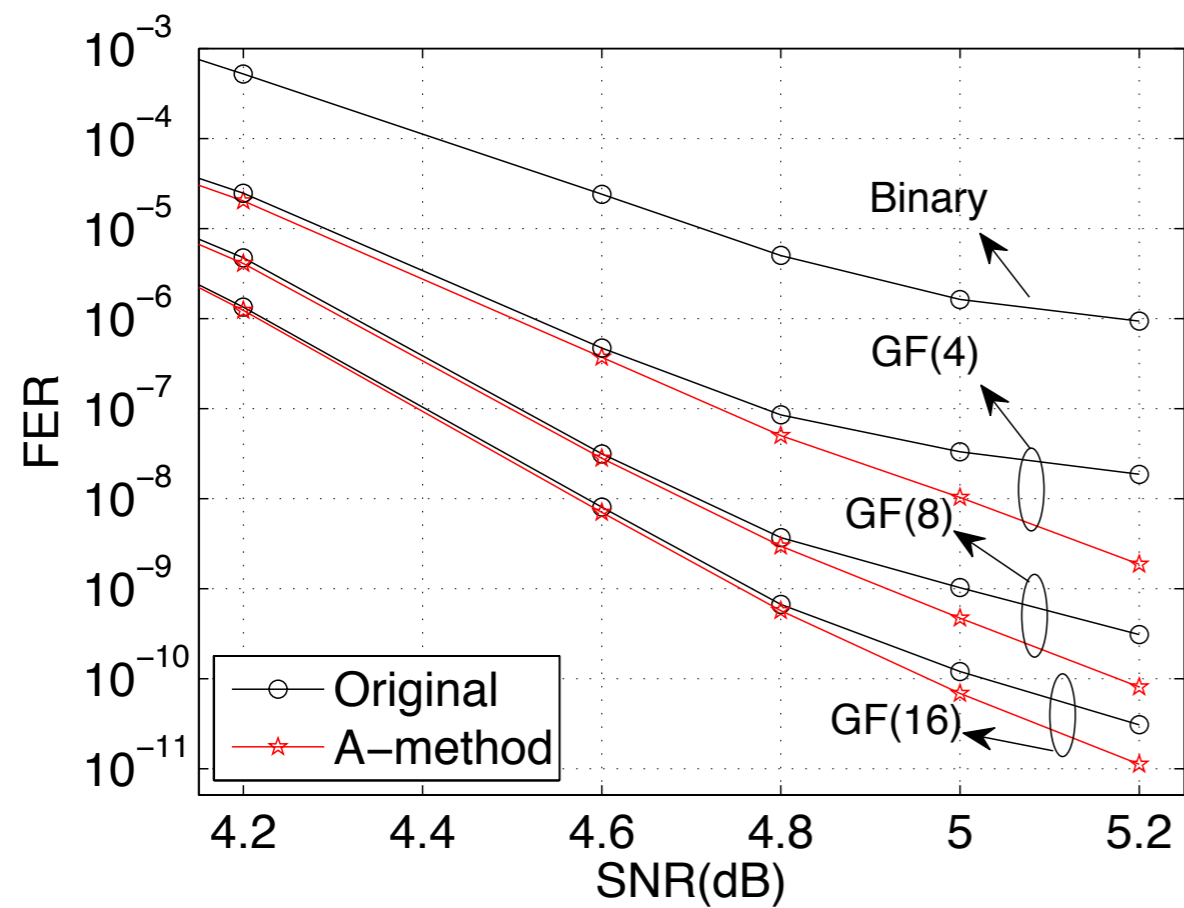
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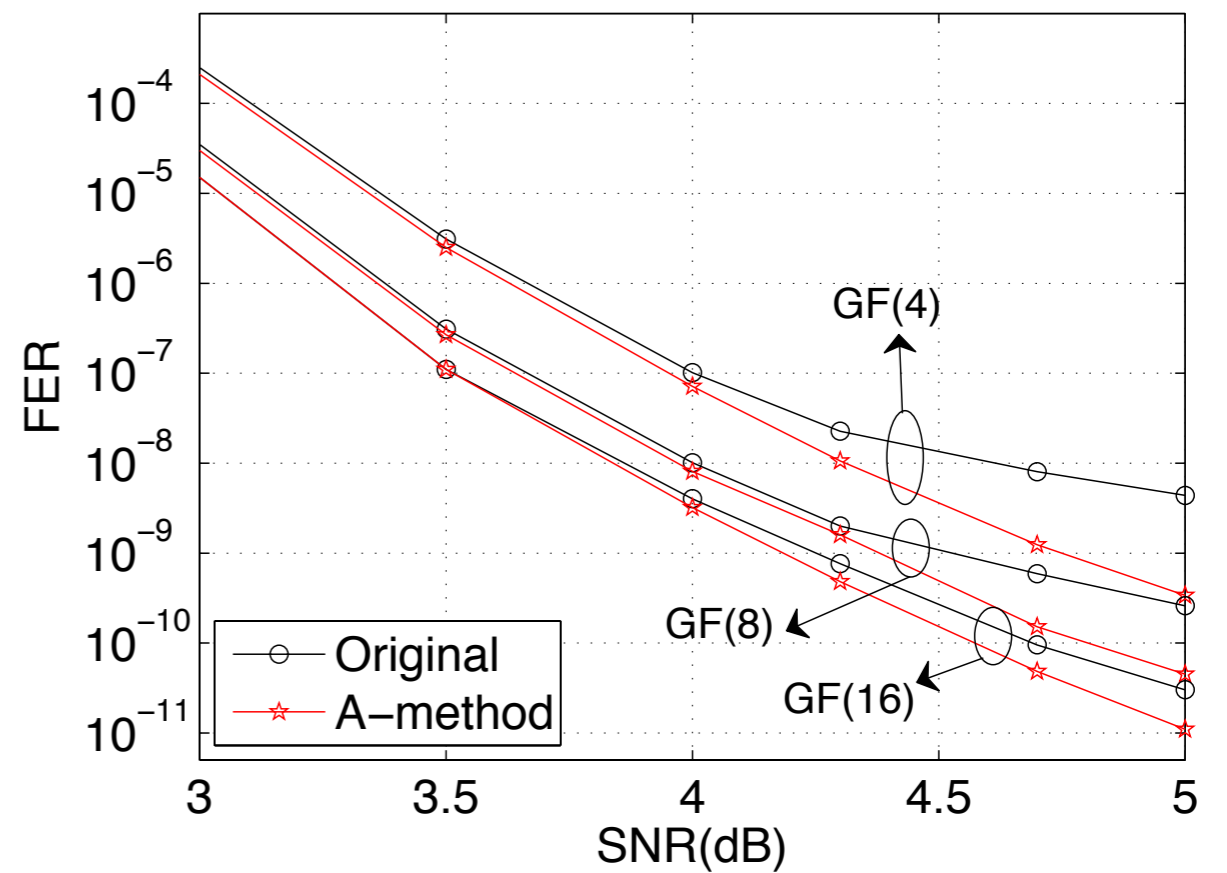


Non-Binary LDPC Codes: Performance

Random codes, $N \approx 2350$, $R \approx 0.83$



QC codes, $N \approx 1200$, $R \approx 0.8$



[Amiri, Kliewer, Dolecek 2014]

- First constructive technique to **provably achieve channel capacity** with bounded complexity $O(n \log n)$ [Arikan 2009]

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- Closely related to Reed-Muller codes, constructed recursively via Kronecker products
- Advantages for **multi-terminal setups** (e.g., broadcast channel [Mondelli et al. 2014])

Take Aways

5G requirements: One code fits all?













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	Low complexity en-/decod.	Finite block-length perf.	Spectrally efficient	Suitable for multi-terminal
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5G requirements: One code fits all?

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- Open:
- Improving finite block length performance of polar codes
 - Non-binary SC-LDPC codes

- B. Amiri, A. Reisizadeh, J. Kliewer, L. Dolecek: Optimized array-based spatially-coupled LDPC codes: An absorbing set approach, Submitted to *ISIT 2015*.
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