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"Strong in Theory, Strong in Practice"

Overview of
UCLA Communication Systems Lab

Richard Wesel

CODESS Workshop, September 19, 2013

http://www.seas.ucla.edu/csl/

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Outline

- Who we are
- What have we done lately
- What are we going to do today

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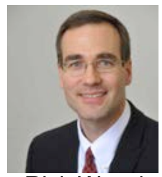
CSL Research Group


Lara Dolecek


Rick Wesel


Dariush Divsalar


Tsung-Yi Chen

Broadcom Intern


Adam Williamson

Northrop Grumman


Kasra Vakilinia

Western Digital Intern


Harsha Bhat

Amazon Lab 126 Intern


Sudarsan Ranganathan

Could be your Intern

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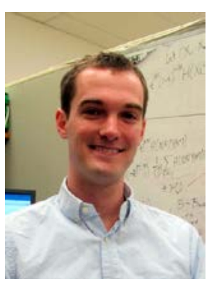
Recent CSL Alumni


Tom Courtade
Assistant Professor
at Berkeley


Jiadong Wang
Senior Engineer
At Qualcomm


Bike Xie
Senior Engineer
at Marvell

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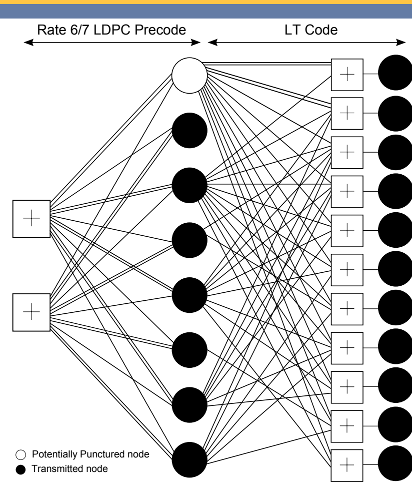
Protograph-Based Raptor-Like LDPC codes



T.-Y. Chen, D. Divsalar and R. D. Wesel,
"Protograph-Based Raptor-Like LDPC Codes with Low Thresholds". ICC 2012, Ottawa, Canada, June 2012.

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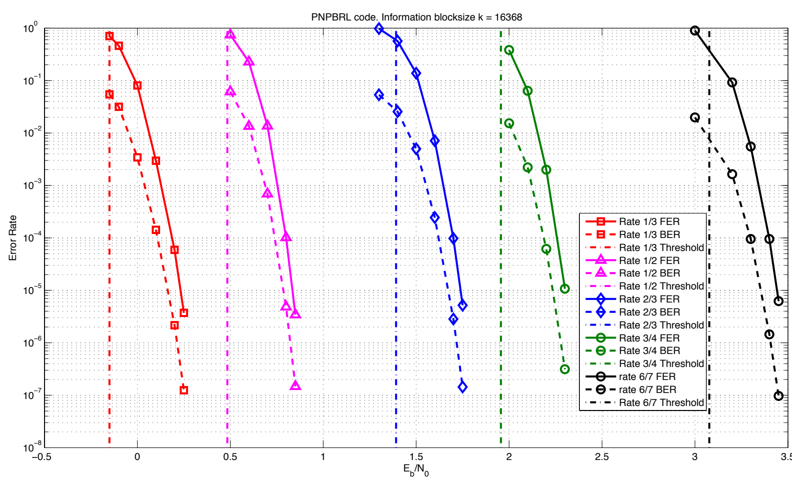
Support a wide range of rates



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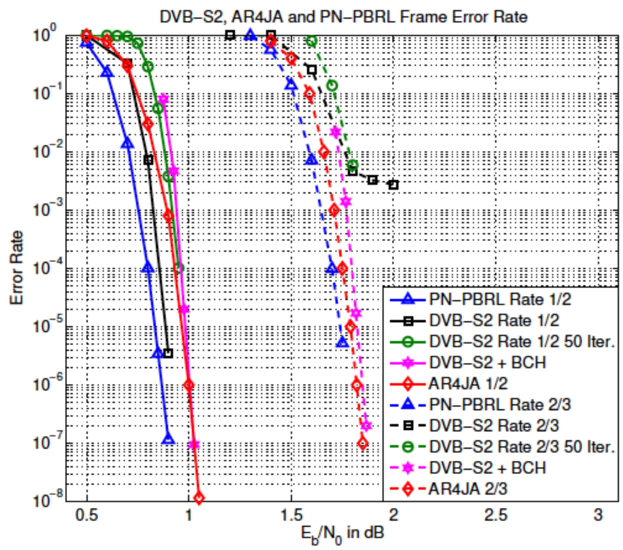
With the good performance at both high and low rates



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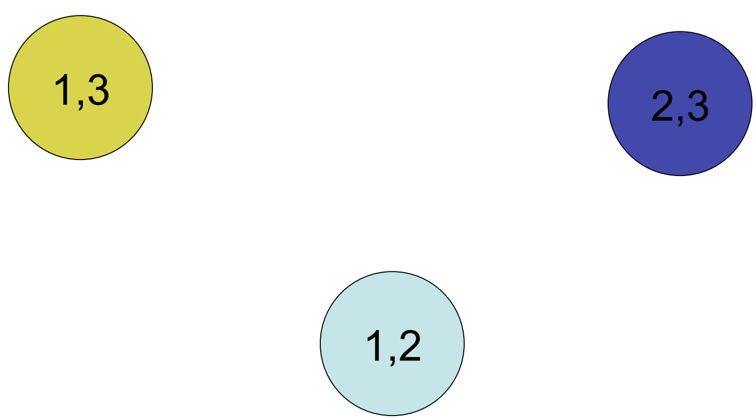
Universal Recovery



T. A. Courtade and R.D. Wesel, **Coded Cooperative Data Exchange in Multi-Hop Networks," to appear in IEEE Transactions on Information Theory**

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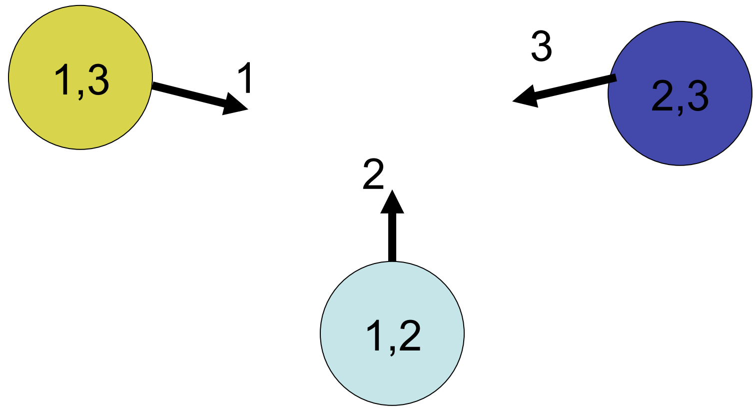
Naïve Solution



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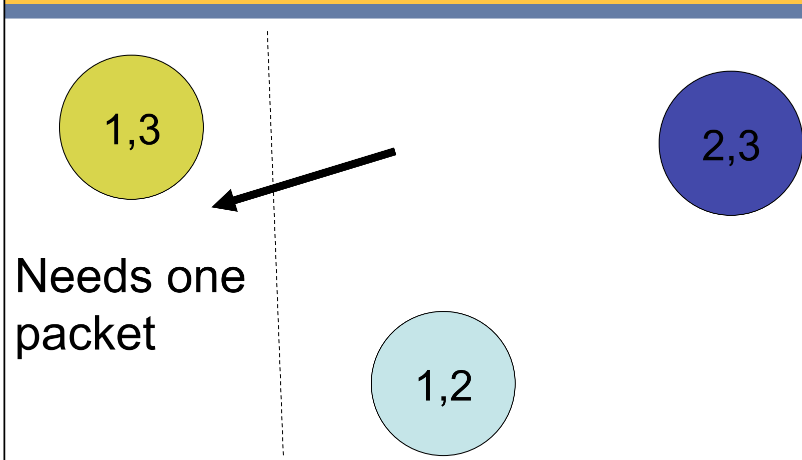
Cut-Set Bounds



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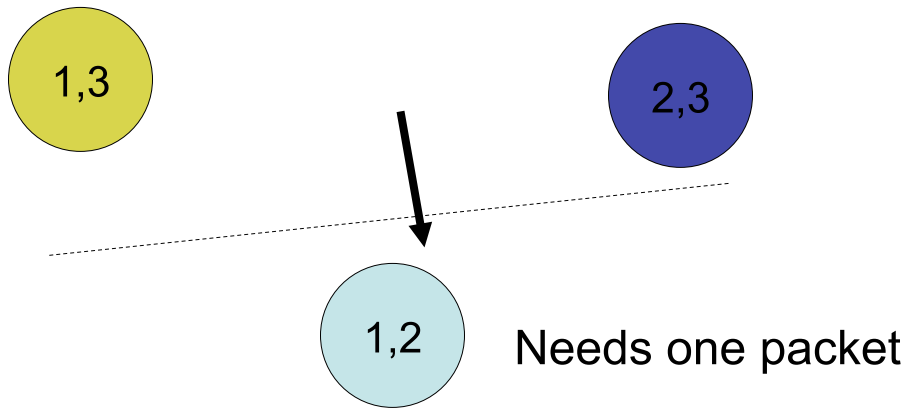
Cut-Set Bounds



T. A. Courtade and R.D. Wesel, **Coded Cooperative Data Exchange in Multi-Hop Networks," to appear in IEEE Transactions on Information Theory** 11

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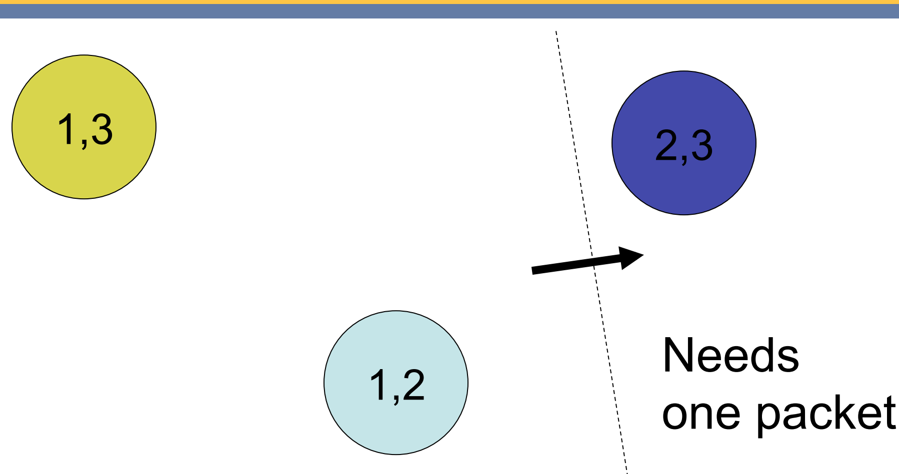
Cut-Set Bounds



T. A. Courtade and R.D. Wesel, **Coded Cooperative Data Exchange in Multi-Hop Networks," to appear in IEEE Transactions on Information Theory** 12

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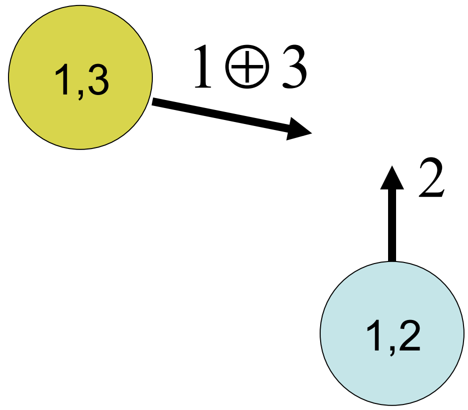
Integer linear programming
Solution requires two transmissions



T. A. Courtade and R.D. Wesel, **Coded Cooperative Data Exchange in Multi-Hop Networks," to appear in IEEE Transactions on Information Theory**

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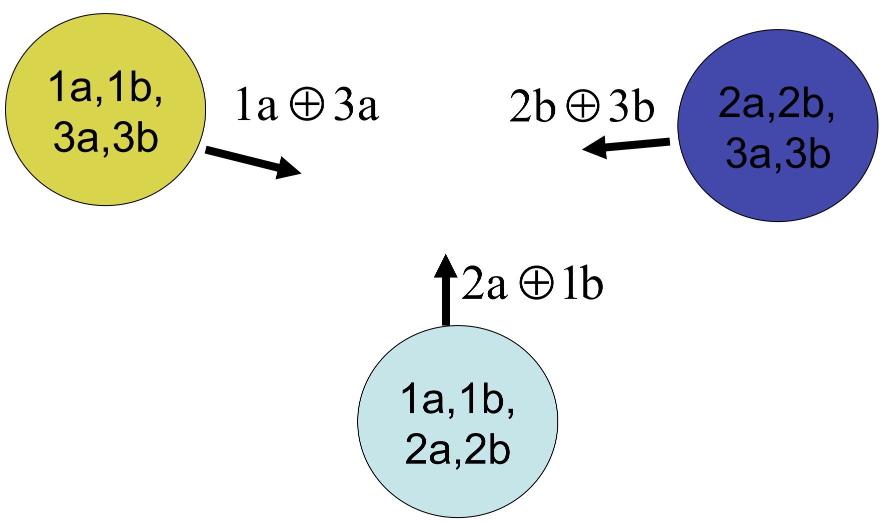
Achieving cut-set bound



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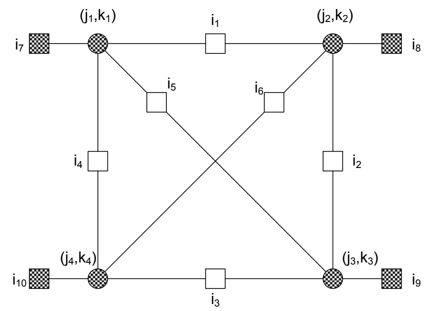
Cycle Consistency Matrix Approach for LDPC Code Design

A (4,4) absorbing set



J. Wang, L. Dolecek and R. Wesel, "
The Cycle Consistency Matrix Approach to LDPC Absorbing Sets in Separable Circulant-Based Codes," IEEE Transactions on Information Theory, Vol. 59, No 4, pp 2293 - 2314, April 2013.

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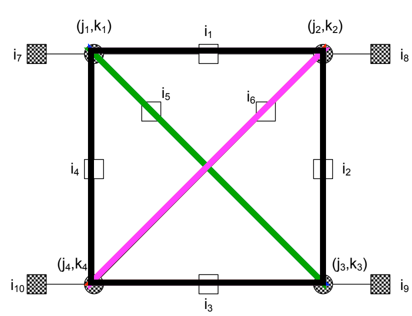
Absorbing Sets have cycles

- We can analyze and even avoid absorbing sets by analyzing and avoiding the cycles that comprise them.
- How many cycles do I really need to consider?



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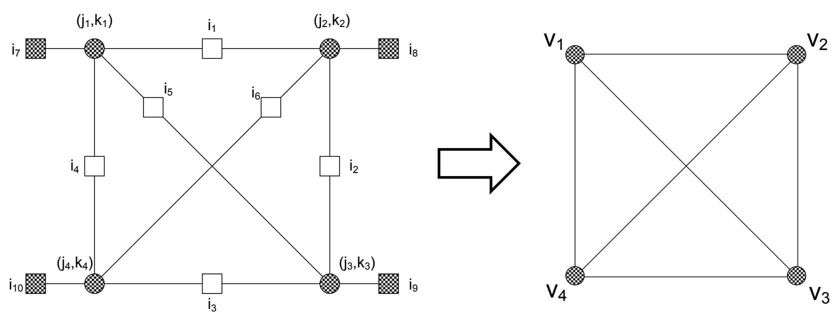
Finding a minimal set of cycles

- Represent the Tanner graph as an unoriented graph where each vertex is a variable node. Two vertices are connected iff there is a check node that connects them.



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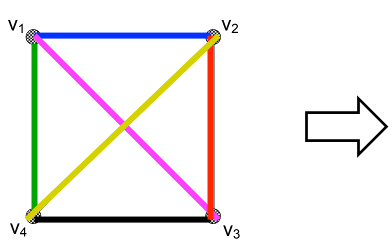
Finding a minimal set of cycles

- Find the incidence matrix of this graph. (Each column is an edge. Each row is a vertex.)



$$B_{\mathrm{as}} = \begin{bmatrix} 1 & 1 & 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 0 & 1 & 1 \end{bmatrix}$$

The null space of B is exactly the space of all cycles (and unions of cycles).

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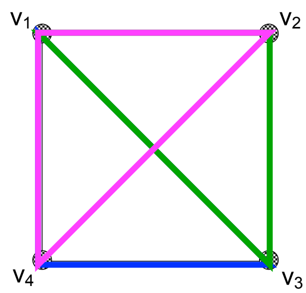
Finding a minimal set of cycles

- For our example, the null space of B has rank 3.
- We need three linearly independent cycles to analyze/avoid all cycles.



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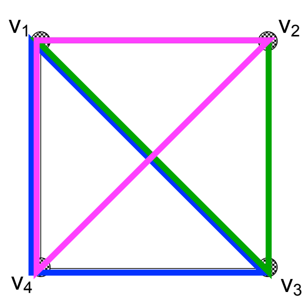
Cycle consistency Matrix

- Define $u_m = j_m - j_1$, to transform the cycle consistency condition to $\sum_{m=2}^{t}(i_{m-1} - i_m)u_m = 0.$



$$\mathbf{Mu} = \begin{bmatrix} i_1 - i_2 & i_2 - i_5 & 0 \\ i_1 - i_6 & 0 & i_6 - i_4 \\ 0 & i_5 - i_3 & i_3 - i_4 \end{bmatrix} \begin{bmatrix} u_2 \\ u_3 \\ u_4 \end{bmatrix} = 0$$

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A necessary and sufficient condition for certain absorbing sets.

- $\mathbf{Mu} = 0$ is always a necessary condition for an absorbing set to be present.
- This is a valuable tool for avoiding absorbing sets by forcing $\mathbf{M}$ to have a nonzero determinant or by precluding $\mathbf{u}$ from being in the null space of $\mathbf{M}$.
- Lemma 1: the necessary and sufficient condition of the existence of (4,4) absorbing sets in a SCB LDCP codes $H_{p,f}^{4,p-1}$ is $\det \mathbf{M} \equiv 0 \bmod p$

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Current CSL Thrusts

- Providing a theoretical foundation for the practical use of feedback to optimize communication systems.
- The combination of set-partitioning and modern codes for performance close to capacity with high spectral efficiencies.
- Optimization of Flash memory performance and lifetime.

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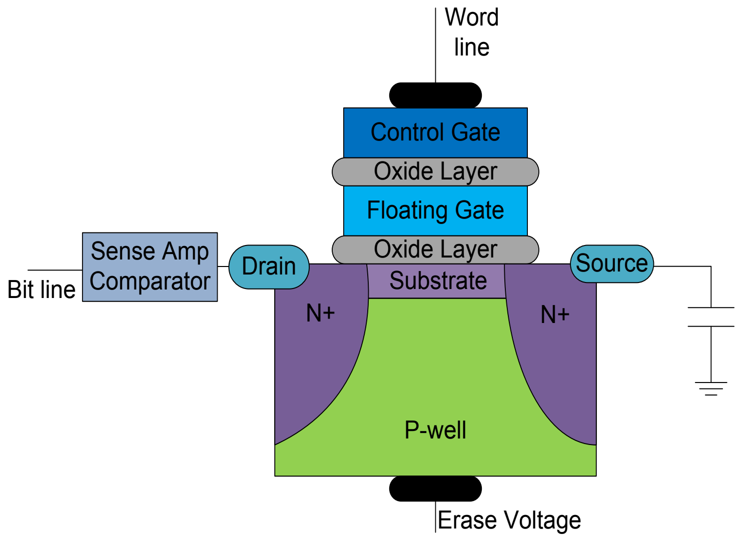
CSL Flash Research Topics



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CSL Flash Research Topics

- Flash memory sensing threshold optimization
- Modeling of Flash memory cells
- Dynamic voltage allocation to extend lifetime
- Histogram based assessment and mitigation of retention loss.
- Progressive memory sensing using optimized word-line voltages
- LDPC code design across a range of precision levels
- Coding with set-partitioning for multilevel cells.

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Today's CSL Student Presenters

Kasra
Vakilinia

Western Digital
Intern

Adam
Williamson

Northrop
Grumman

Sudarsan
Ranganathan

Could be
your Intern

Enhanced Precision Through Multiple Reads For LDPC Coding in Flash Memories

Dynamic Voltage Allocation Based on Mutual Information for Nand Flash Memory

Combining Modern Codes and Set-Partitioning for Multilevel Storage Systems

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