Overcoming LDPC Trapping Sets with Informed Scheduling

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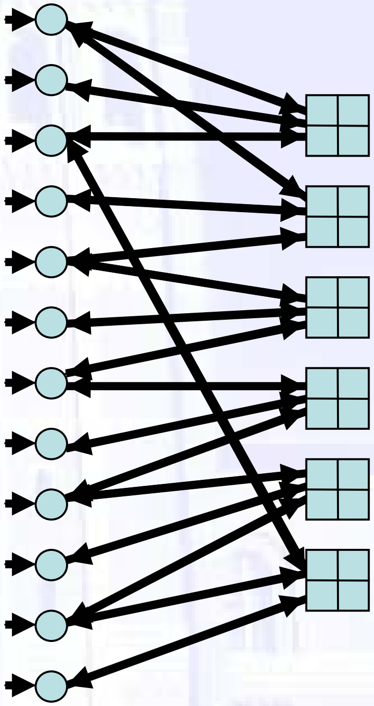
Outline

- Message-passing scheduling
  - Simultaneous vs sequential loopy BP
  - Sequential scheduling problem
- Informed scheduling strategies:
  - Residual Belief Propagation (RBP)
  - Node-wise RBP
- Reduced complexity strategies
- Informed scheduling and trapping sets
- Conclusions and open problems

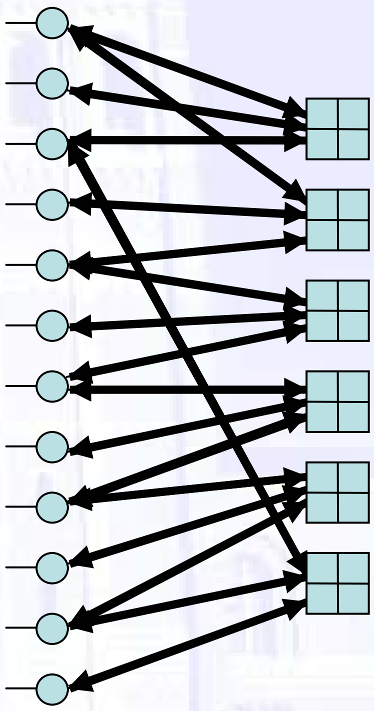
Simultaneous (Flooding) Schedule

- On every iteration
  - All variable nodes are simultaneously updated
  - All check nodes are simultaneously updated



Standard Sequential Schedule (SSS)

- Update messages sequentially:
  - [Mansour 03] (CN sequence)
  - [Kfir 03] (VN sequence)
  - [Hocevar 04] (LBP)
  - [Sharon 04] (Serial Schedule)
  - [Zhang 05] (Shuffled BP)
  - [Radosavljevic 05]
- Has been shown to converge at twice the speed than simultaneous scheduling
- What is the best sequence?



Residual Belief Propagation (RBP)

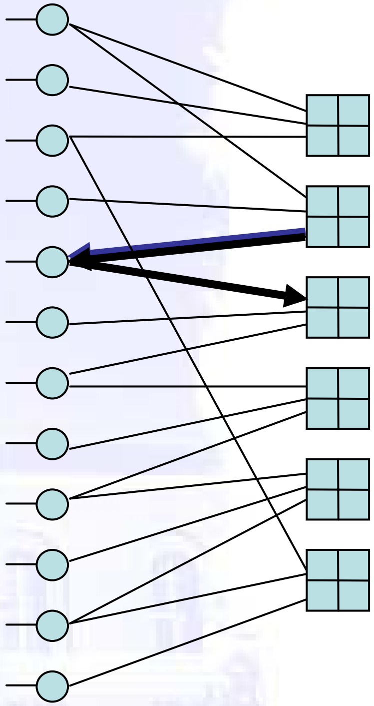
- Algorithm proposed by Elidan et al. for general loopy BP solutions
- Define residual as:

$$r = \left\| m_{new} - m_{old} \right\|$$

- As BP converges, the residuals go to 0
- RBP is a greedy algorithm that propagates the message with the largest residual

RBP for LDPC decoding

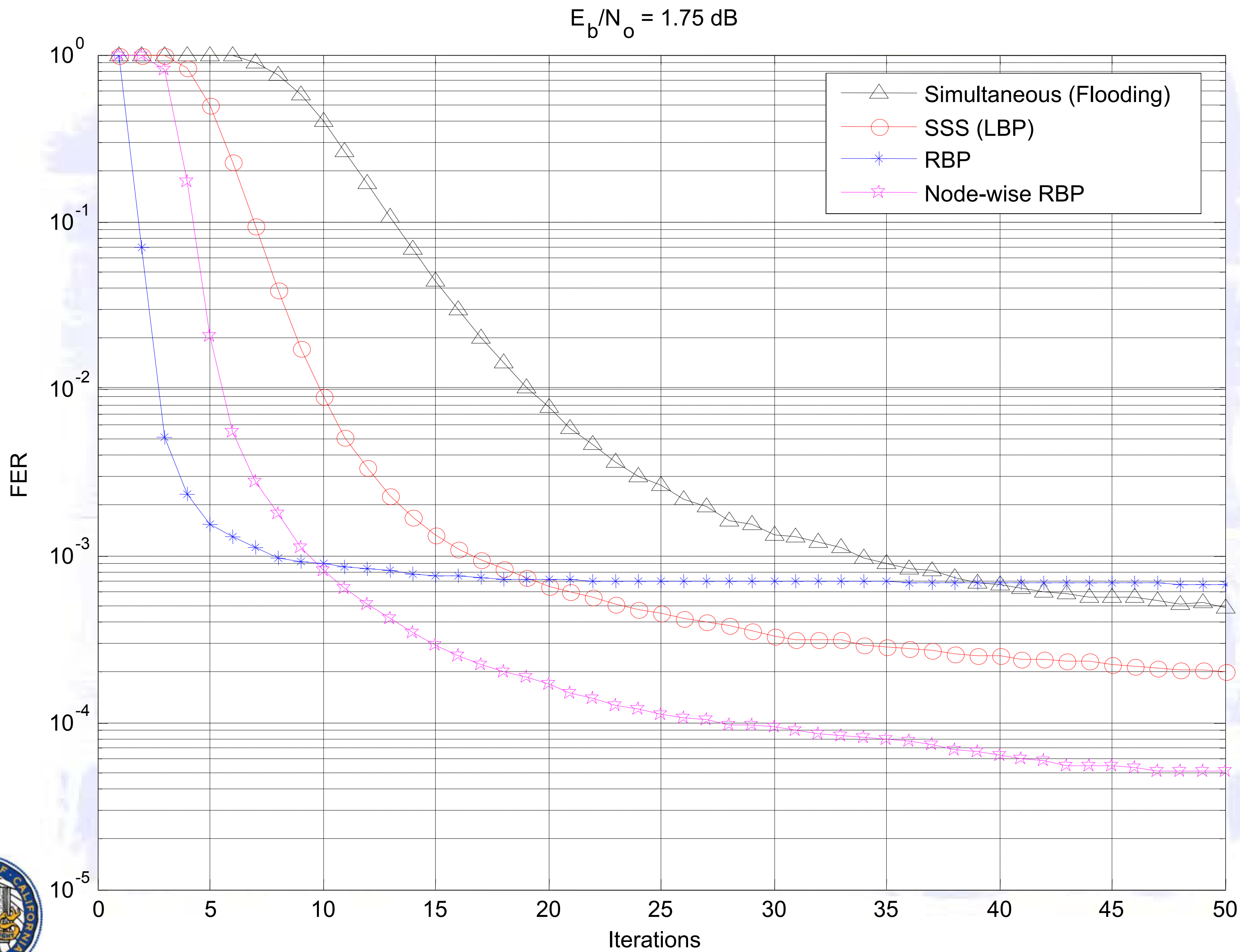
- Propagate message with biggest residual
- The variable-to-check messages that change will have the same residual so they are the biggest
- Therefore, RBP can be simplified
  - Propagate check-to-variable message with biggest residual
  - Propagate variable-to-check messages that change



Node-wise RBP

- RBP greediness makes it converge faster but less often
- Node-wise RBP simultaneously propagates all the outgoing messages from a check node
- The check-node updated is the one that has the message with the biggest residual
- This means that correcting messages are simultaneously send to all variable nodes that could be in error
- Node-wise RBP converges less fast than RBP but more often

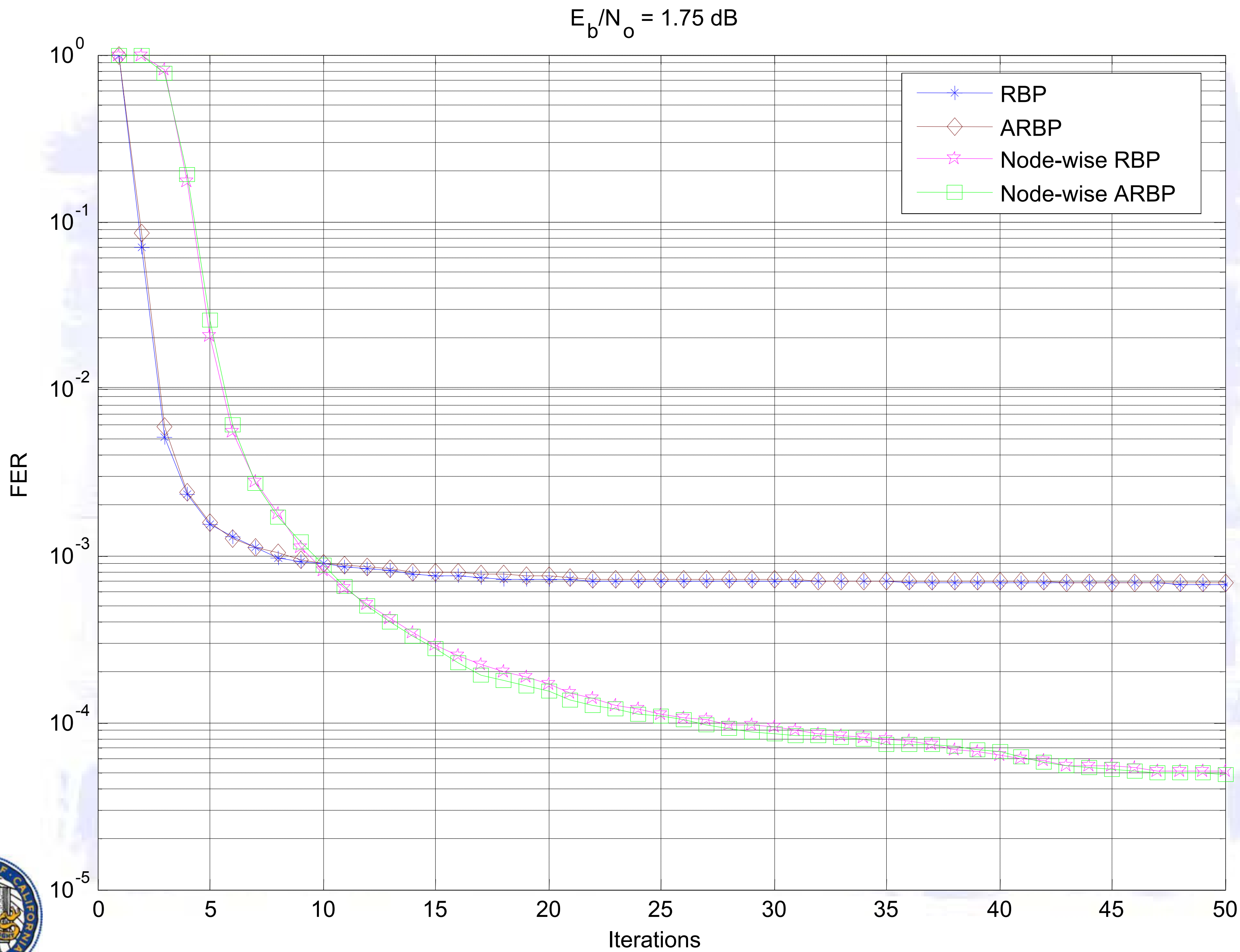
Results


E_b/N_o = 1.75 dB
Simultaneous (Flooding)
SSS (LBP)
RBP
Node-wise RBP
FER
Iterations
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
0
5
10
15
20
25
30
35
40
45
50

Complexity

- Residual computation requires the values of the messages to be propagated
- Many of those computations are then "wasted" since many of those messages aren't propagated
- Using the min-BP check-node update to compute residuals significantly reduces the complexity
- Approximate RBP (ARBP) and node-wise ARBP are the min-BP versions of RBP and node-wise RBP respectively

Results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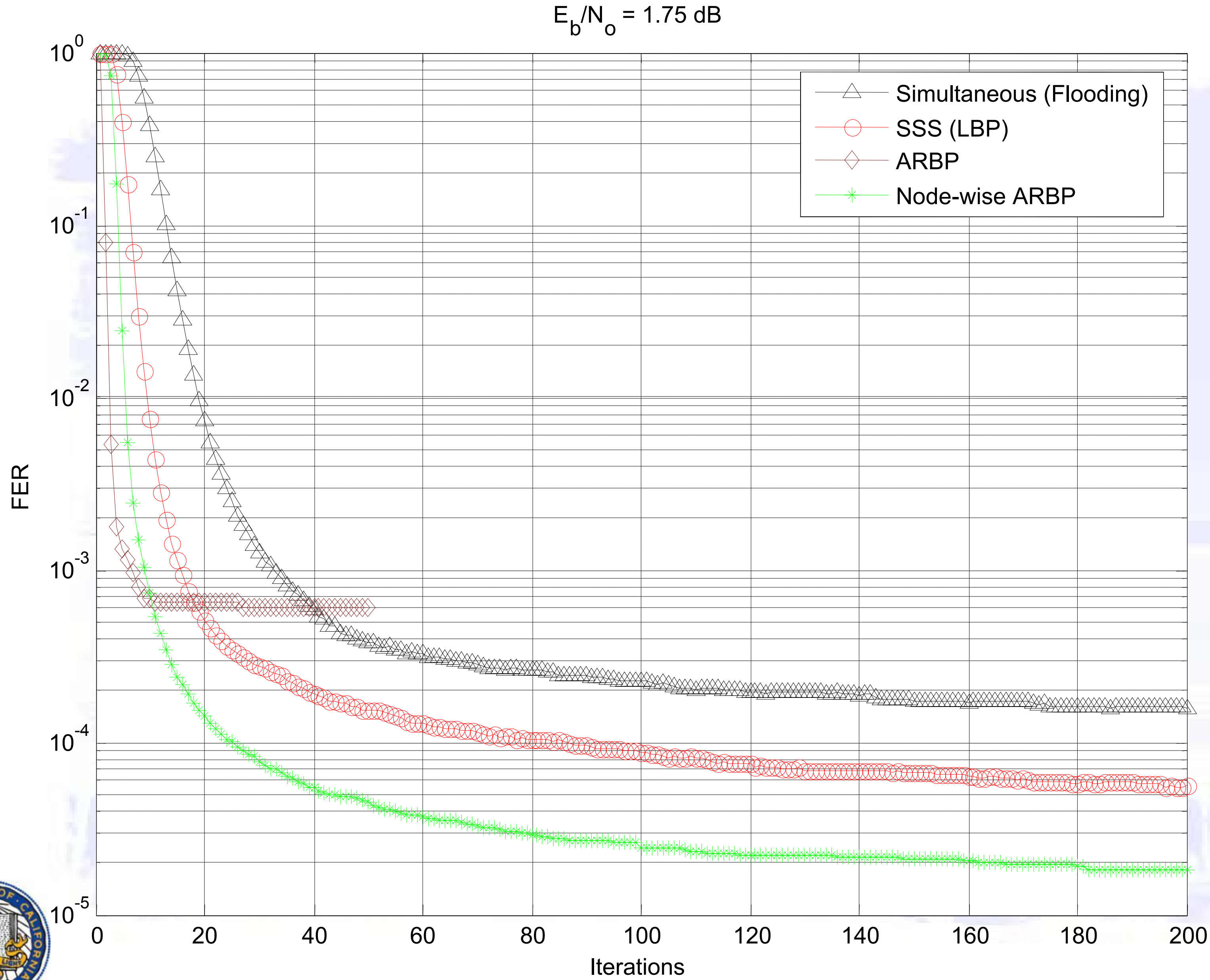
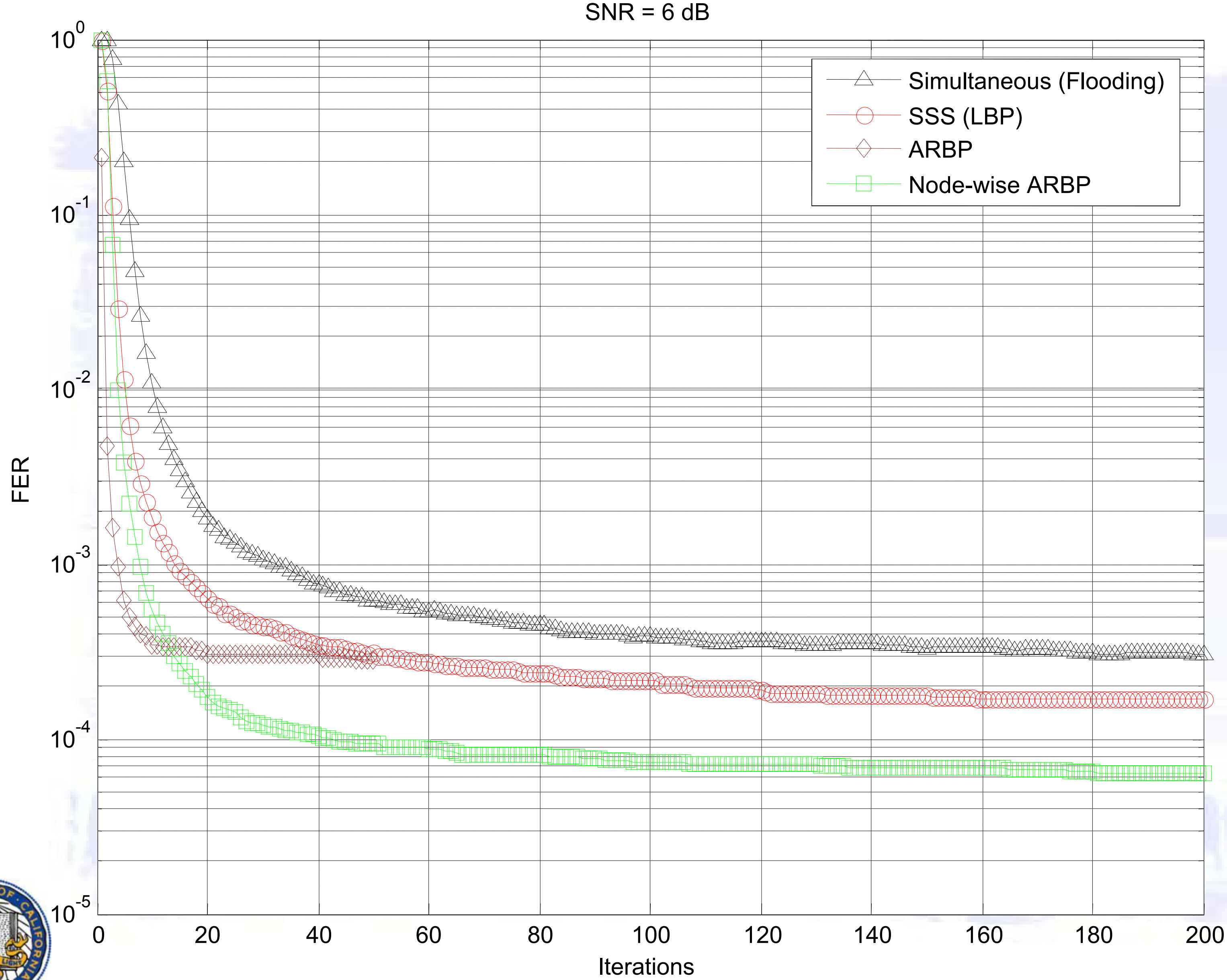
Results 802.11n code rate 1/2



Results 802.11n code rate 5/6



Why does informed scheduling work faster?

- As mentioned before RBP focuses on the part of the graph that has not converged thus there are less "wasted" updates
- Furthermore, our informed scheduling strategies tend to chose to update nodes that have recently received new information

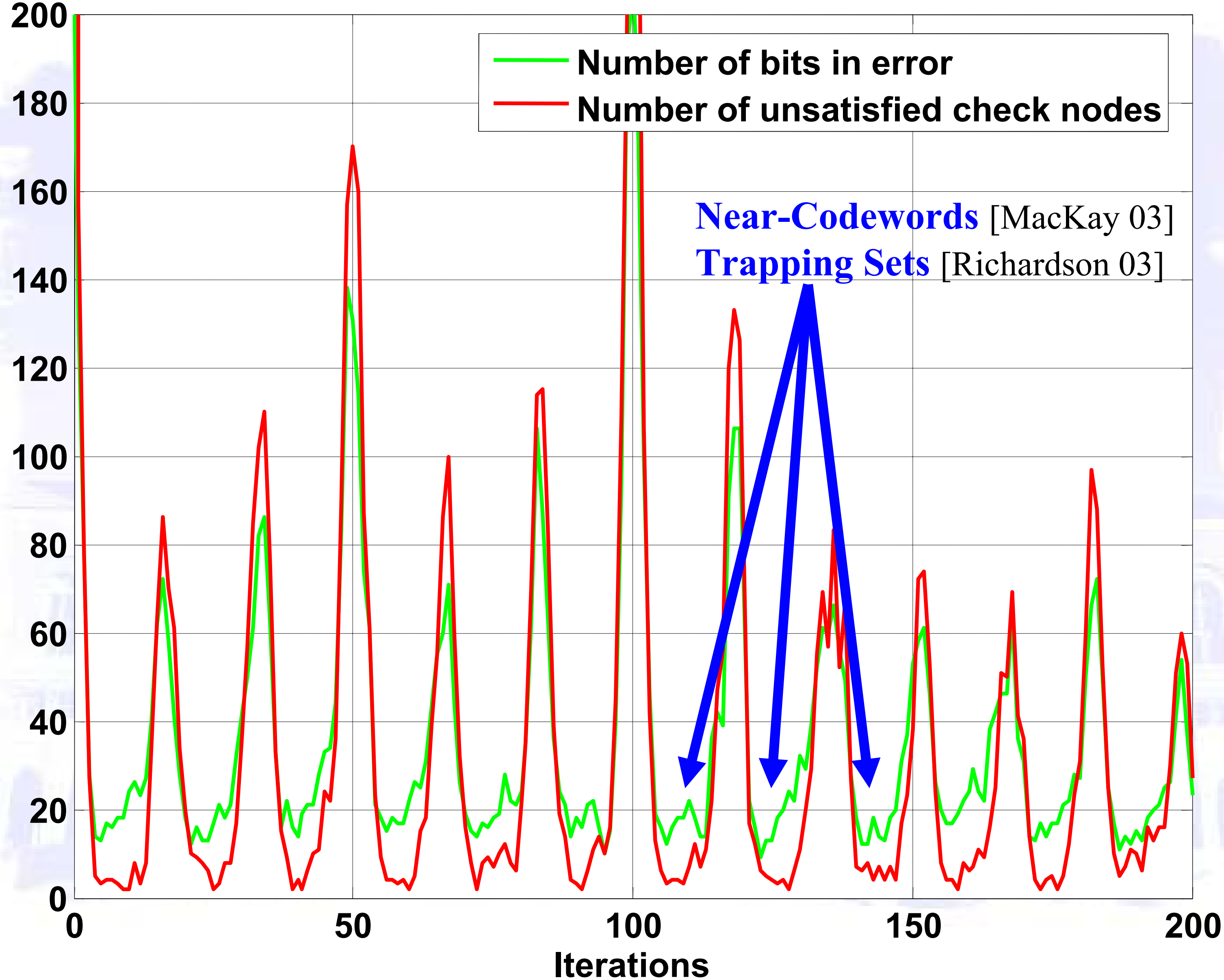
We understand faster, but why better?

- Performance plots show that our informed scheduling strategies perform not only faster but better than SSS
- There are many noise realizations that aren't corrected after 200 SSS iterations but are corrected after few NW-ARBP iterations
- This difference can't be explained with the argument of the "wasted" updates

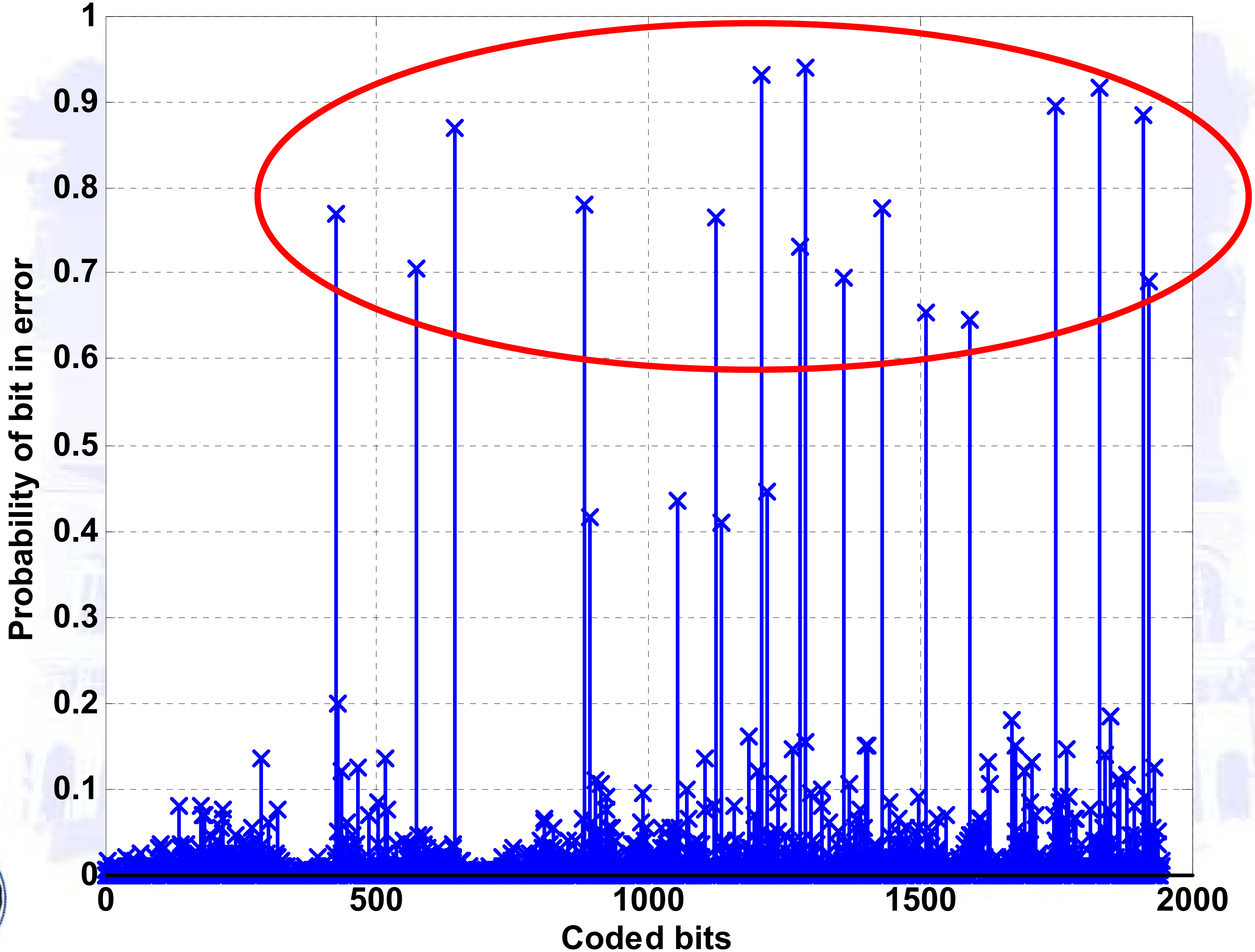
SSS Errors

- Let us characterize the following type of noise realizations
  - AWGN Channel
  - SSS (LBP) decoding doesn't converge after 200 iterations
  - NW-ARBP iterations converges after few iterations
  - Rate ½ 802.11n code
  - n=1944, k=972
  - SNR = 1.75 dB, waterfall region
- Most of these errors look similar let us see an example

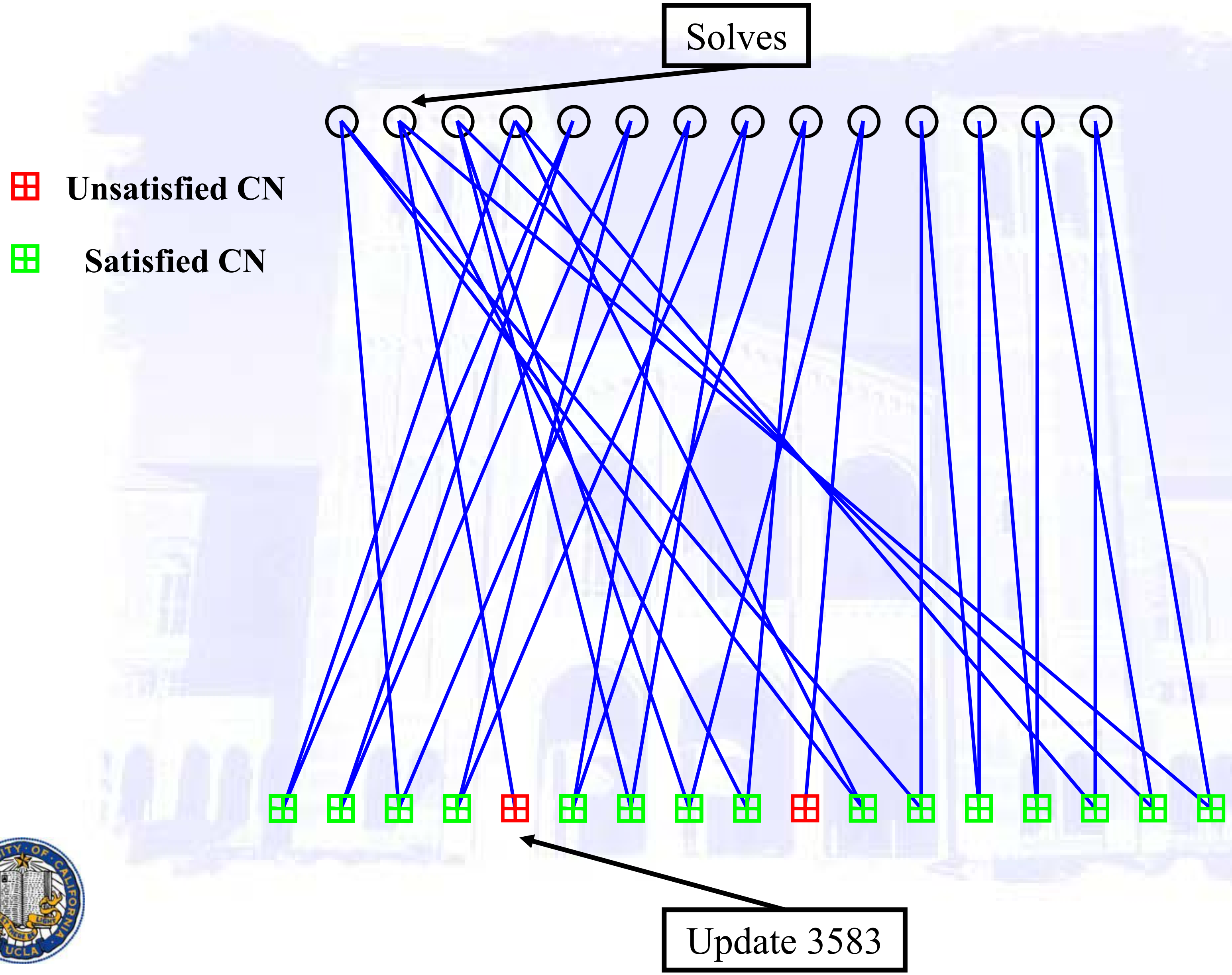
SSS (LBP) decoding behavior



SSS (LBP) decoding behavior



Informed Scheduling and Trapping Sets



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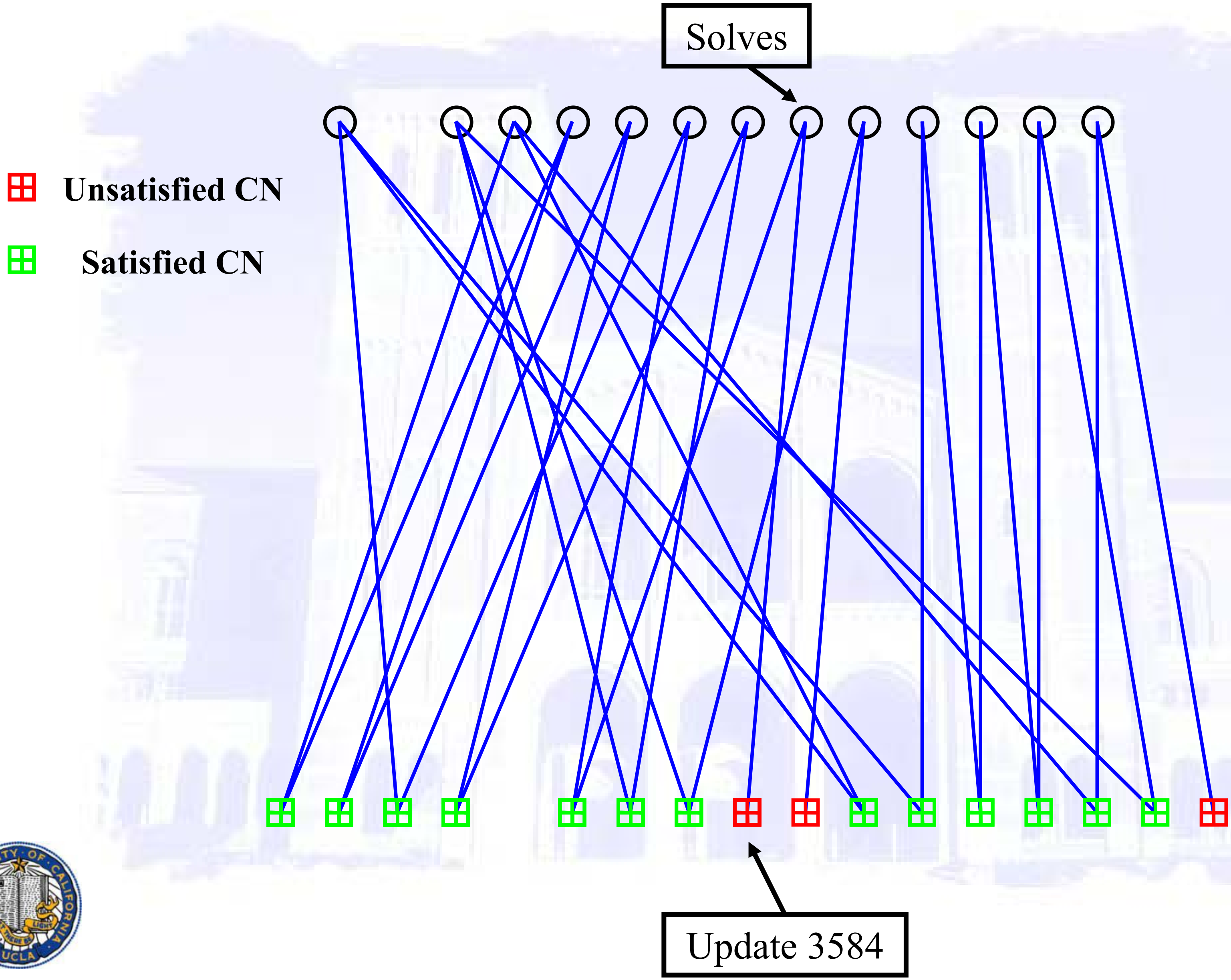

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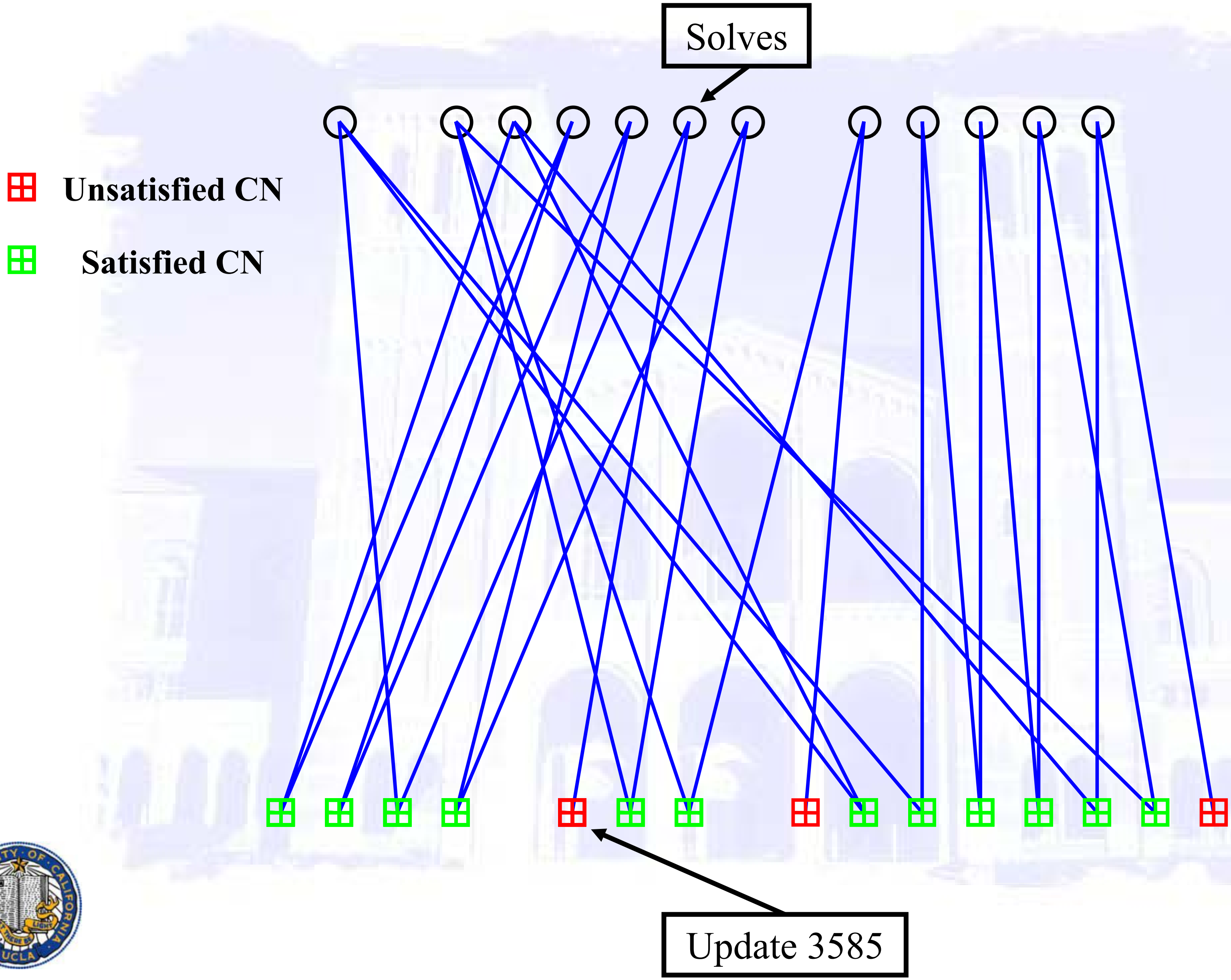

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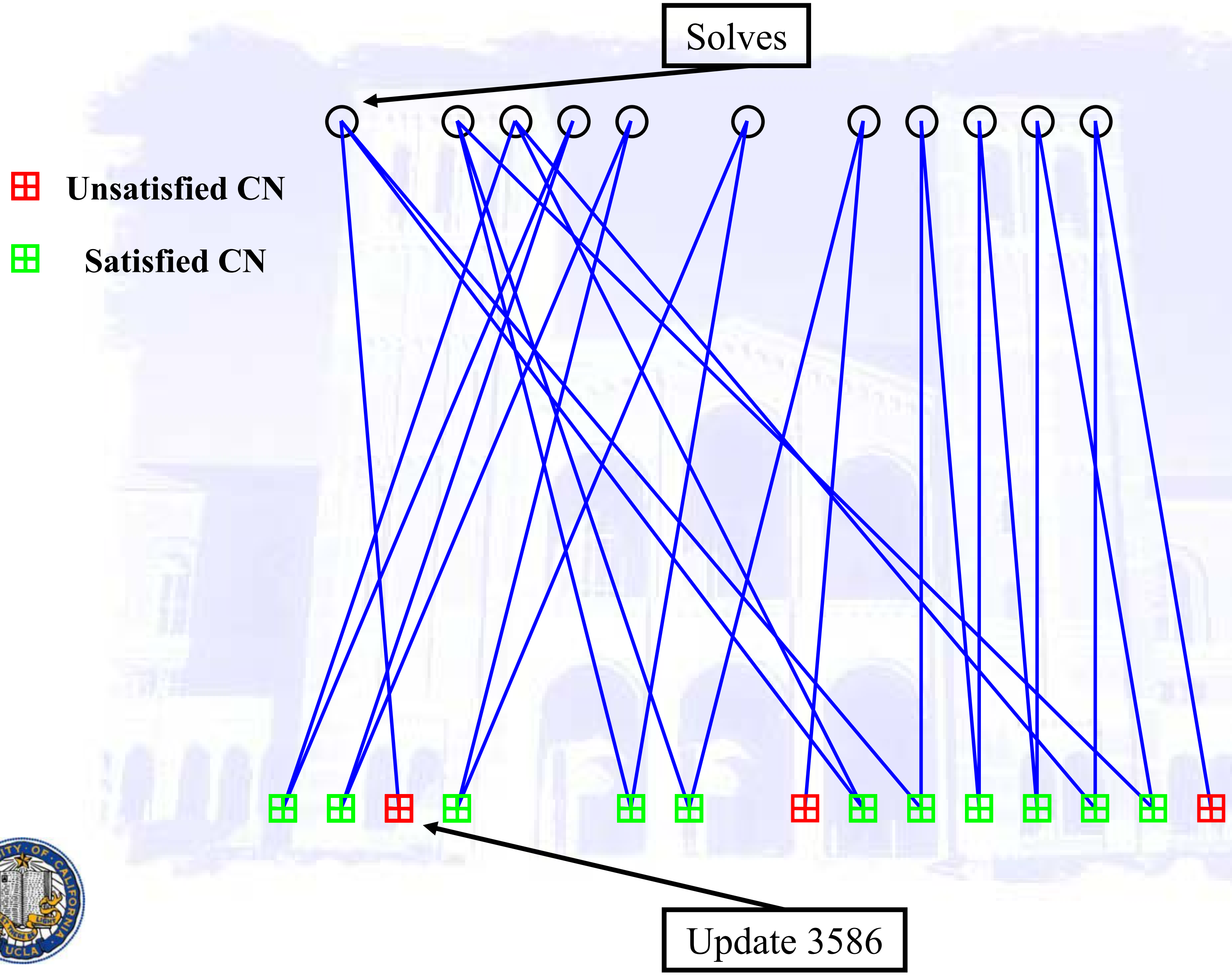
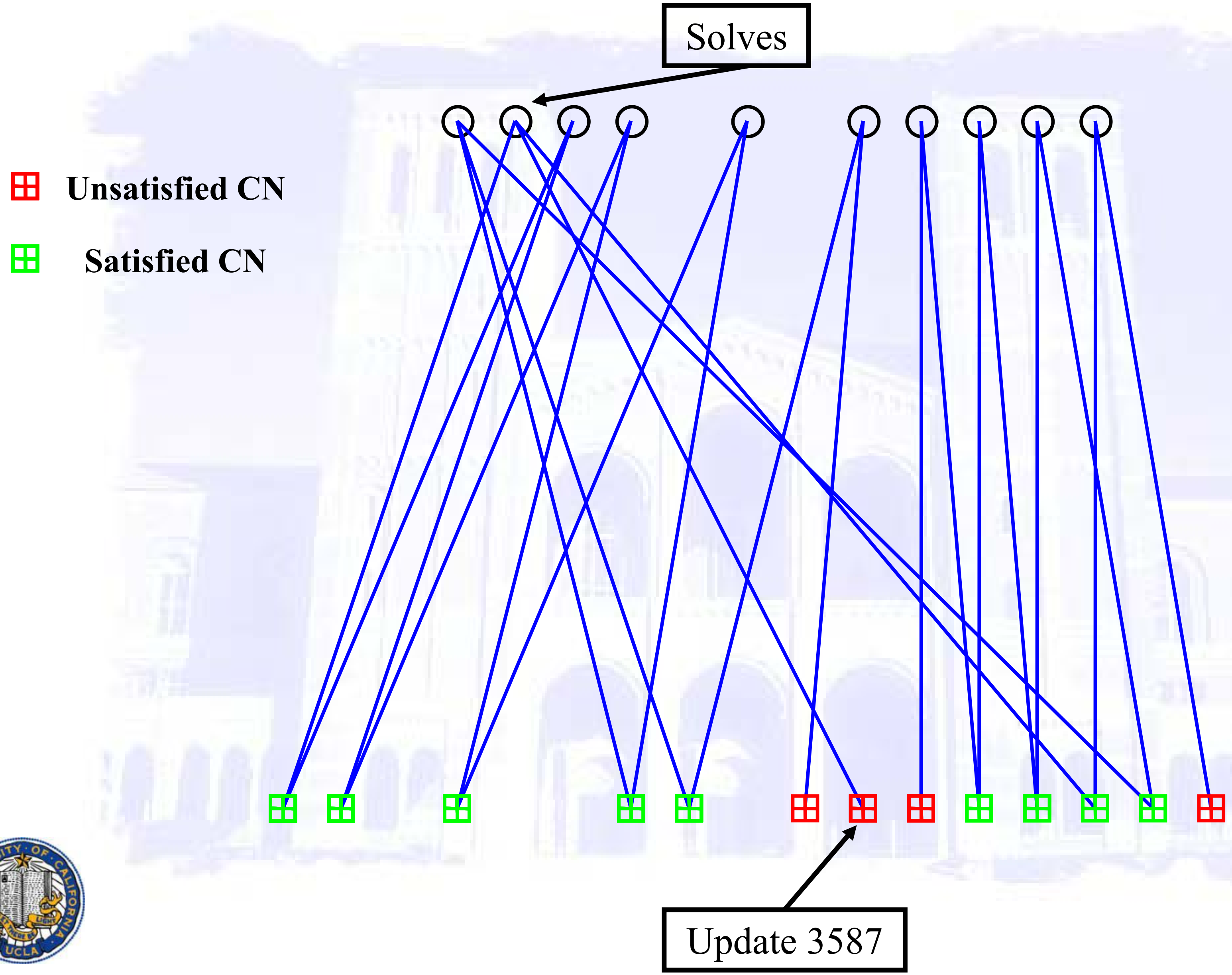
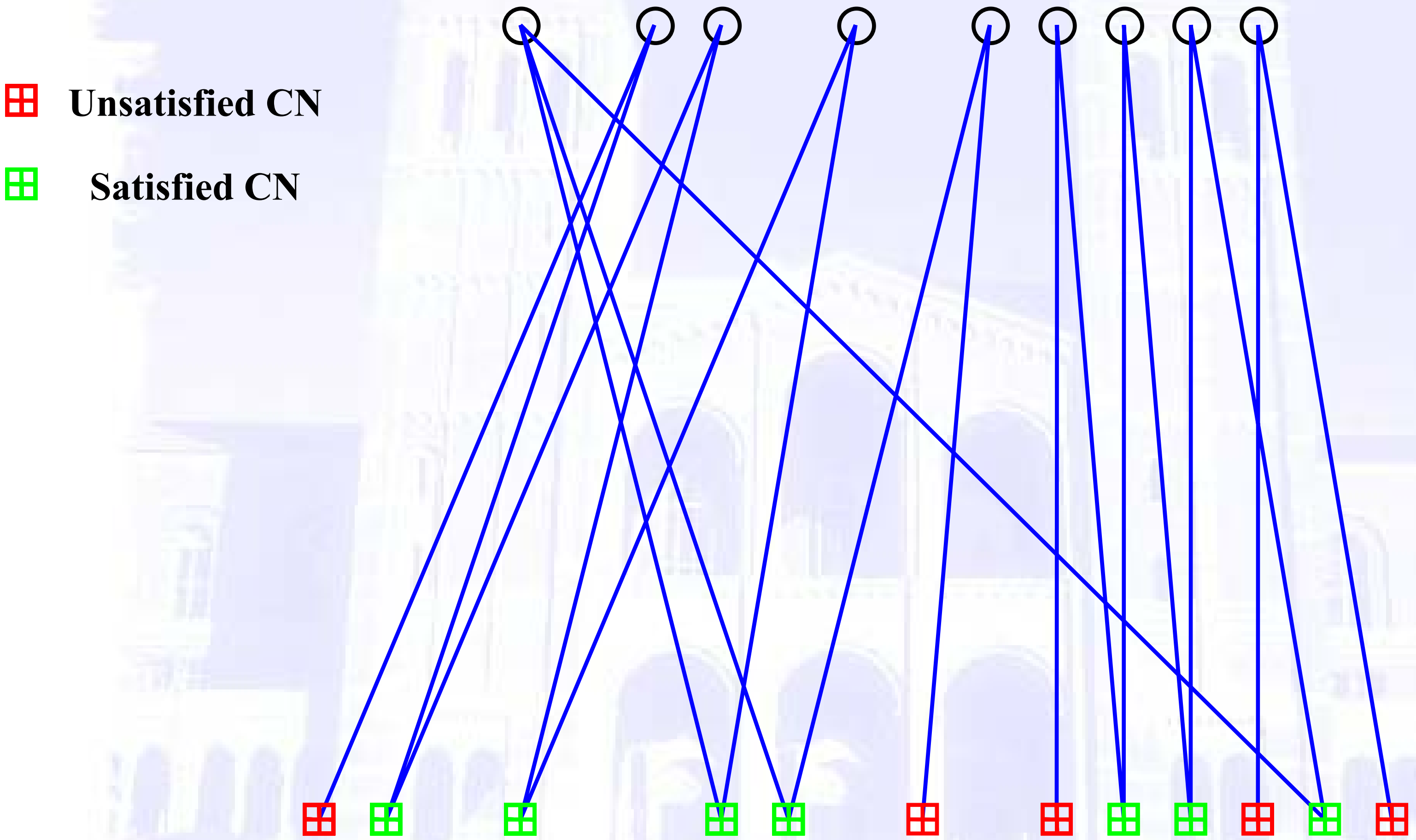


Informed Scheduling and Trapping Sets



Informed Scheduling and Trapping Sets



Conclusions

- Scheduling significantly affects the performance of loopy BP LDPC decoding
- RBP and ARBP are good strategies for a small number of iterations or high target error-rates
- Node-wise RBP and node-wise ARBP perform better than SSS for all iterations
- Furthermore, NW-ARBP helps solve trapping set errors

Open problems

- Informed scheduling on the error-floor region
- Joint SSS (LBP) and informed scheduling
- Extensions to other applications that use loopy BP:
  - Turbo Codes
  - Turbo equalization
  - Joint demodulation and decoding
- Extensions to applications outside the communications area