Reduced Complexity Decoding Algorithm of LDPC Codes Using Node Elimination

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Outline

General Belief Propagation Algorithm

- check node message updating rule

$$L_{mn} = \ln \frac{1 - \prod_{n' \in N(m) \backslash n} \frac{1-\exp(z_{mn'})}{1+\exp(z_{mn'})}}{1 + \prod_{n' \in N(m) \backslash n} \frac{1-\exp(z_{mn'})}{1+\exp(z_{mn'})}}$$

  - L_{mn} : the LLR of bit n in check m
  - z_{mn} : LLR of bit n which is sent from the bit node n to check node m
  - $N(m) \backslash n$: the set of bits that participate in check m except for the bit n

General Belief Propagation Algorithm

- bit node message updating rule

$$z_n = F_n + \sum_{m' \in M(n)} L_{m'n}$$

$$z_{mn} = z_n - L_{mn},$$

  - z_n : the LLR of bit n
  - F_n : the LLR of bit n which is derived from the received value y_n
  - $M(n)$: the set of checks that participate in bit n.

The elimination of bit nodes with large LLR values

- In tentative decoding step, if the absolute value of z_n is large, the probability that the hard decision of bit n is correct is high.
- The probability that the hard decision of these bit nodes is flipped in the remaining iterative decoding process is low.
- The bit node that has a sufficiently large z_n magnitude can be eliminated from the bipartite graph in order to stop the update of the bit node.

An example of node elimination

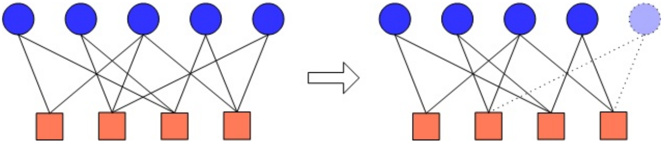

Figure: The bipartite graph representation of node elimination

- In the horizontal and vertical decoding step, the message-passing update through the eliminated node is not activated.

- It maintains only the hard decision value to satisfy the check equation of the associated check nodes.

An example of node elimination

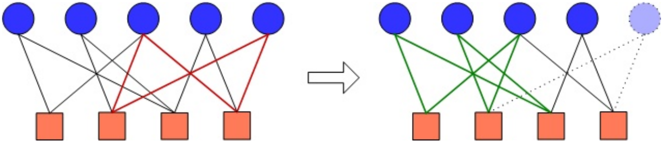

Figure: The bipartite graph representation of node elimination

- After the fifth bit node is eliminated, the smallest length cycle associated with the third bit node is increased from 4-cycle to 6-cycle.
- Therefore not only can we reduce the complexity, but we can also improve the performance by enhancing the cycle properties.

The selection of eliminated nodes

- To prevent performance degradation, the probability that the hard decision of an eliminated node is incorrect must be smaller than the decoded bit-error probability for the received E_b/N_o.
- If we assume that the transmitted bit $c_n = 0$, the minimum magnitude of z_n for node elimination can be determined as

$$\begin{aligned} |z_n| &= \left| \ln \frac{\Pr(c_n = 1 \text{ at } l'\text{s iteration})}{\Pr(c_n = 0 \text{ at } l'\text{s iteration})} \right| \\ &= \left| \ln \frac{\Pr(\text{hard decision error at } l'\text{s iteration})}{1 - \Pr(\text{hard decision error at } l'\text{s iteration})} \right| \\ &> \left| \ln \frac{\alpha(\text{coded BER at received } E_b/N_o)}{1 - \alpha(\text{coded BER at received } E_b/N_o)} \right| \end{aligned}$$

  - α : parameter for performance adjustment between 0 to 1.

The additional conditions for node elimination

- The signs of F_n and $z_{mn} \in M(n)$ are the same.
- All associated check equations are satisfied.
- All of the above conditions are satisfied during two consecutive iterations.

BER performance

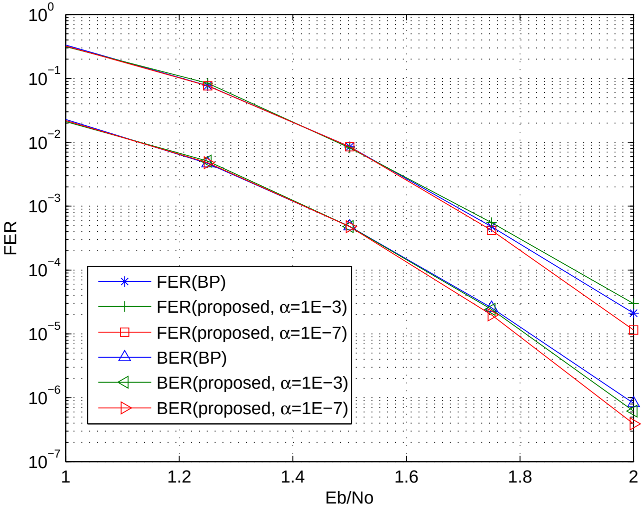

Figure: BER performance of proposed algorithm

The number of eliminated bit nodes

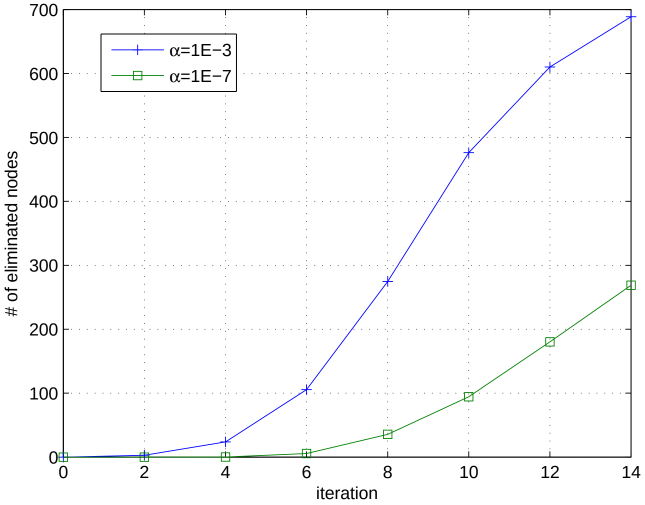

Figure: Number of eliminated nodes through iteration

The enhancement of the cycle properties

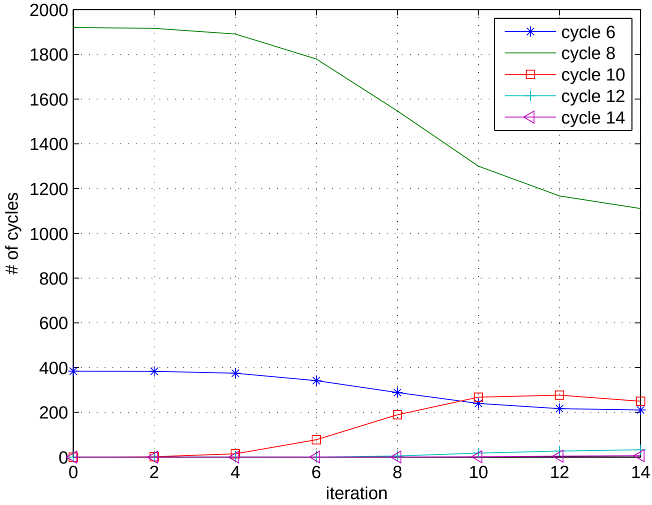

Figure: Enhancement of cycle properties through iteration

Concluding Remarks

- We proposed a modified belief propagation algorithm by using node elimination for the bit nodes of large LLR magnitude.
- By the elimination of the bit nodes requiring iterative computation, we can reduce the decoding complexity and also enhance the cycle properties.
- Simulation results show that the proposed modified BP algorithm outperforms the BP algorithm in the high-E_b/N_o region and the decoding complexity is reduced.