A Research on Improvement of Error Floor of ARA codes

2006. 11. 18

Tae Ui, Kim

Coding and Information Theory Lab.

Contents

- **Motivation**
- **Introduction**
  - Protograph and ARA codes
  - Construction of parity check matrix of ARA codes
  - Some theoretical bases
- **Proposal to improve error floor of ARA codes**
  - Analysis of cycles
  - Proposed algorithms
- **Simulation result**
- **Conclusion**

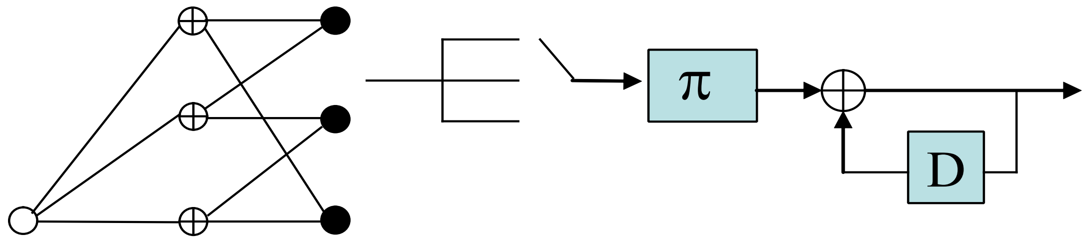
Motivation

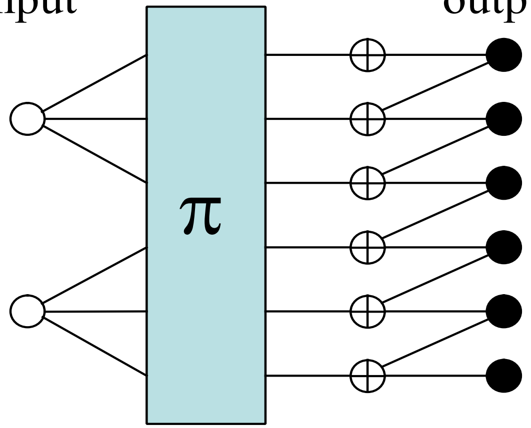
- **ARA codes**
  - Linear time encoding
  - Variable code length
  - Rate compatible code
  - Low threshold
- **High error floor of ARA codes**
  - Small minimum distance of ARA results in high error floor
- **Goal of the paper**
  - Achieve improvement of error floor without loss of performance in waterfall and with a slight burden of complexity

Introduction

RA codes

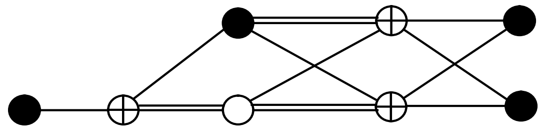
- Repetition + Accumulation
- Contrsuction based on protograph
- Decoded using BP algorithm as a subclass of LDPC codes

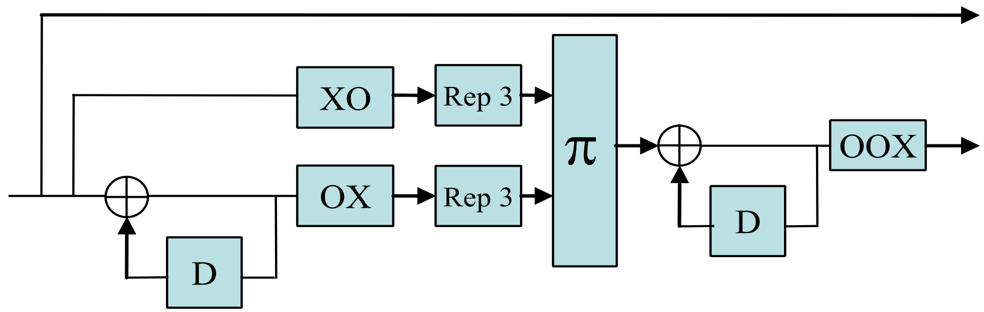




ARA Codes Based on Protograph

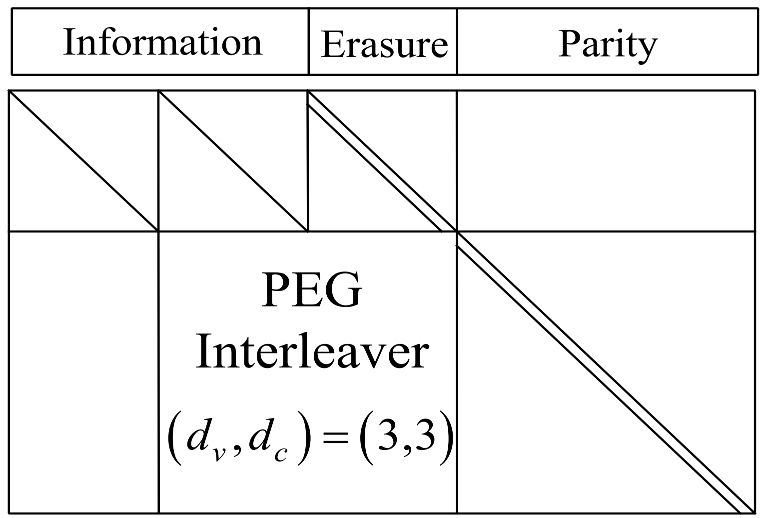
Protograph and Encoder of ARA code





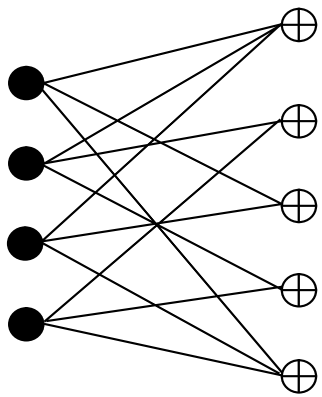
Parity check matrix

- Erasure bits due to intermediate bits and puncturing
- Reducing erasrue bits for decoding convergnece

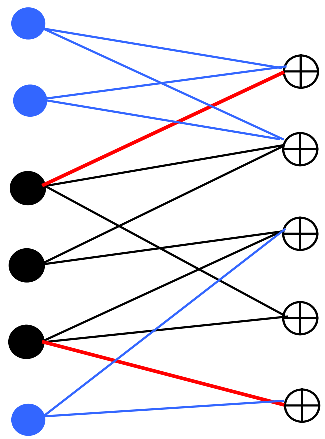


Stopping set and EMD

- **Stopping set**
  - A set of variable nodes whose neighbors are connected to the set at least twice
  - No smaller size of stopping set than t ensures that minimum distance $d_{min} \geq t$
- **EMD (Extrinsic message degree)**
  - Number of extrinsic check nodes
  - A variable node set with large EMD requires additional nodes to be a stopping set



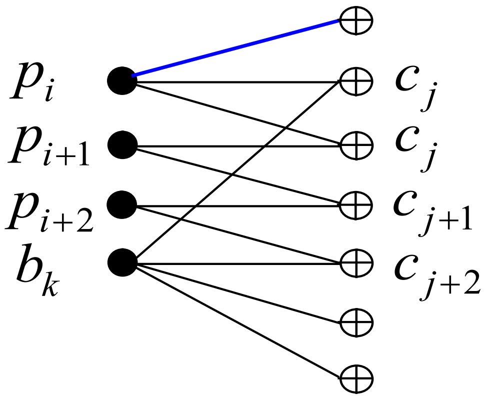
Stopping set of size 4

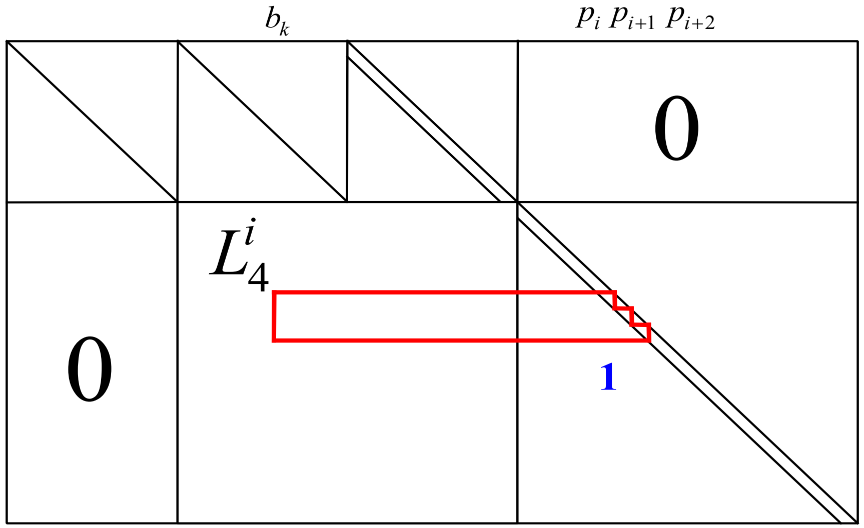


Stopping set of size 6 / A set with EMD 2

Proposal : Analysis of cycles

- **Consecutive parities cycle L_d**



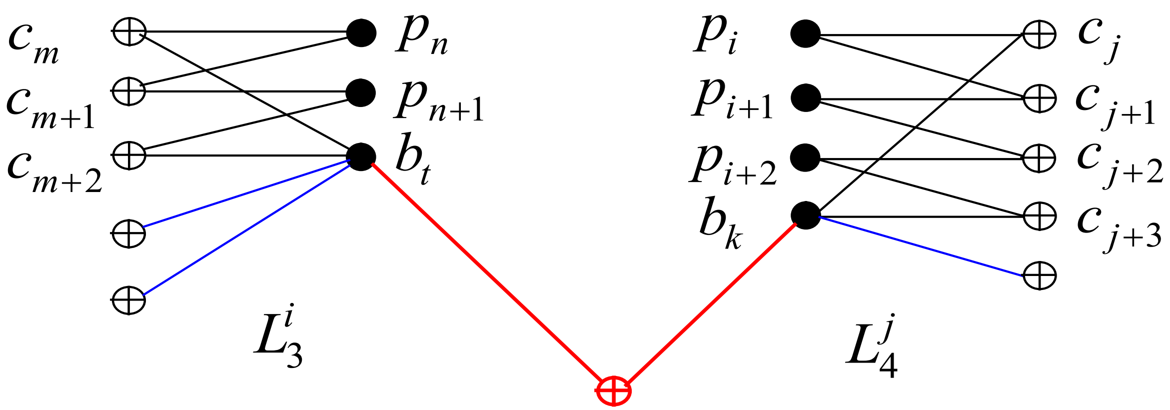


- **EMD of L_d**
  - $EMD(L_d) = Degree(b_k) - 2$
  - Likely to be a small size of stopping set

Proposal : Union EMD

- **Union of L_d's**
  - Some unions of L_d's have interconnection
  - Small size and small EMD for size
  - Consider union of 2 consecutive cycle sets
- **EMD of union**
  - Deficient EMD of union

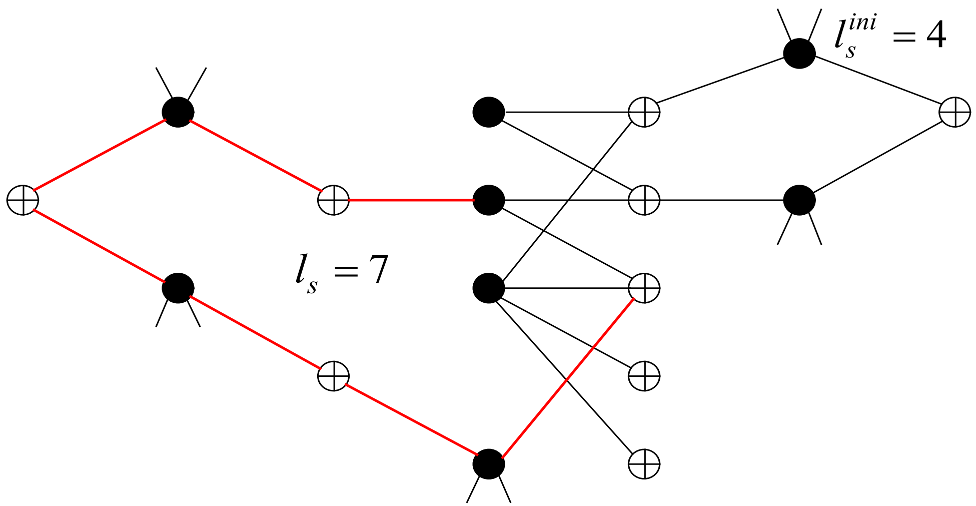
$$E_{Def}(i,j) \quad EMD\left(L_d^i\right)+EMD\left(L_d^j\right)-EMD\left(L_d^i \cup L_{d'}^j\right)$$



Union of 2 consecutive cycle sets with size 7 and EMD 3

Proposal : Self return distance

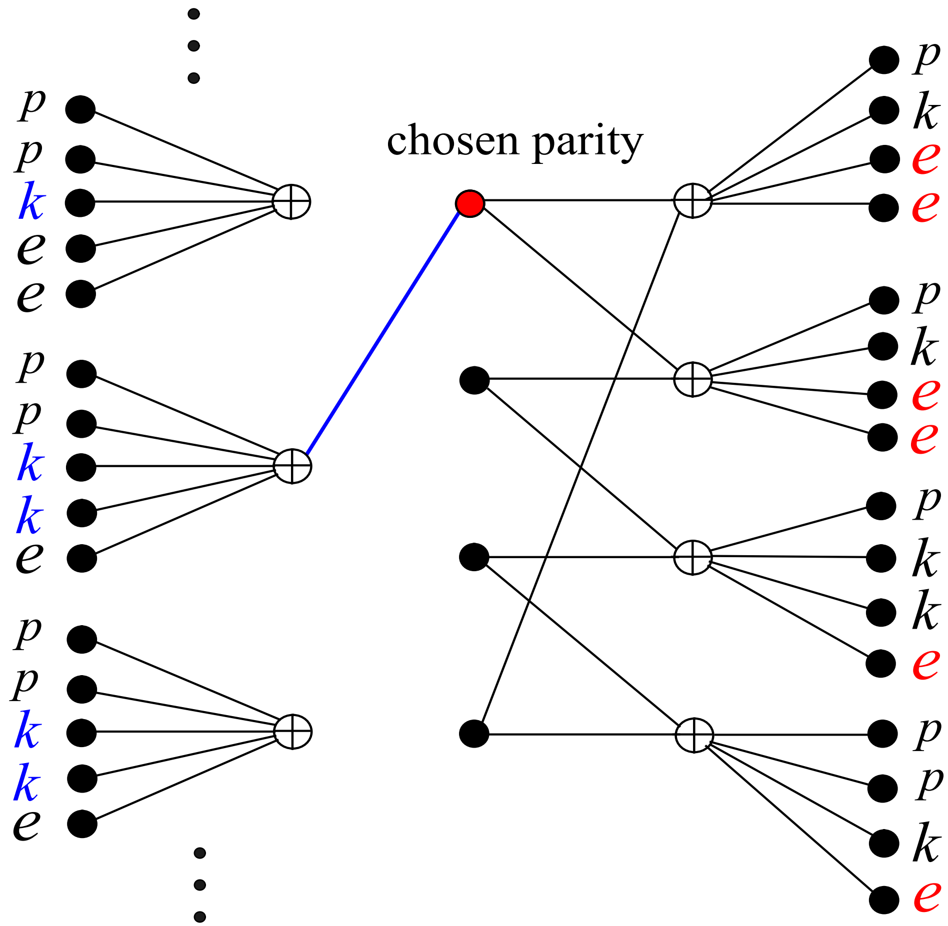
- **Self return distance l_s**
  - Smallest number of edges from L_d to L_d
  - Large l_s will make more bit nodes involved when L_d and other bits node make up stopping set
  - New edge does not decrease l_s



Proposal : Edge connection

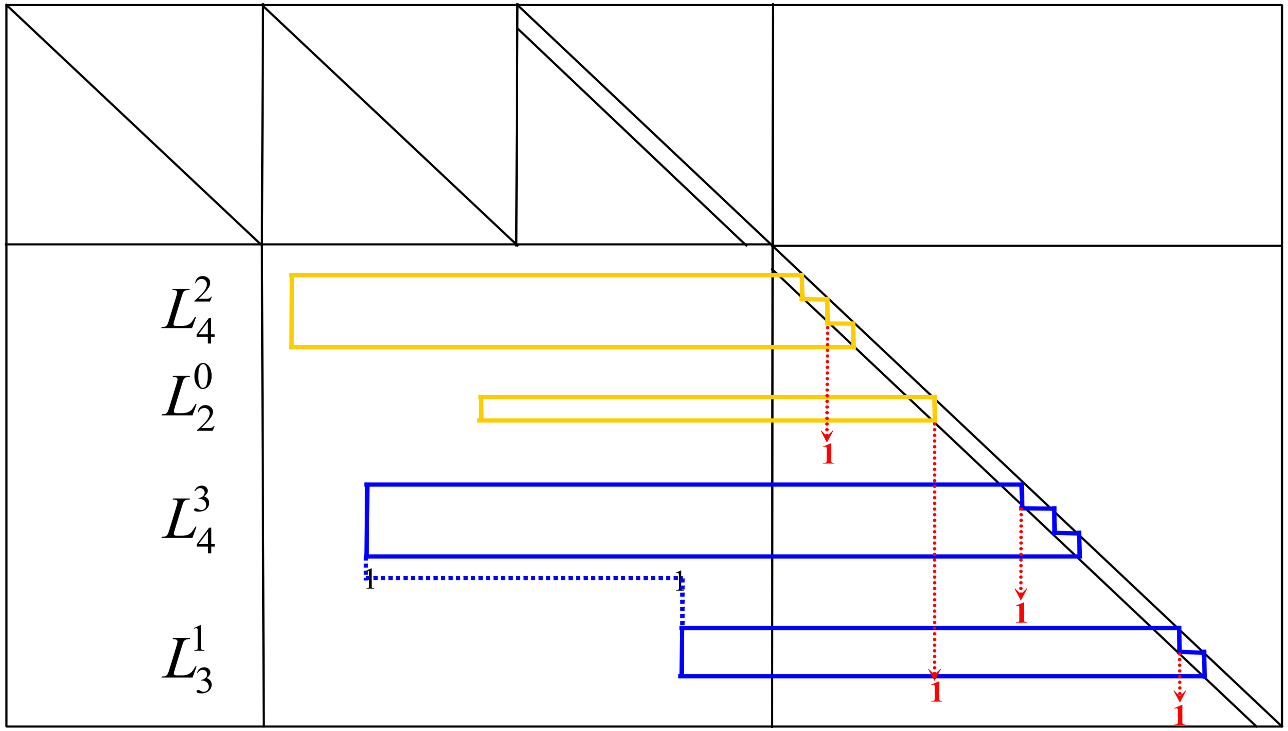
Criterion for new connection

- Selection of a parity bit
  - ✓ Erasure and information connectivity
- Selection of a check node
  - ✓ Erasure and information connectivity
  - ✓ Self return distance
  - ✓ EMD
  - ✓ Maximize resulting cycle length



Proposal : Summary of algorithm

- **1. Identify all the consecutive parity cycles, index from small size cycles**
- **2. Evaluate initial** $E_{Def}(i,j)$ **and** l_s^{ini}
- **3. Add new edge**
  - For consecutive cycle sets with $E_{Def}(i,j) > 0$ until $E_{Def}(i,j) \le 0$
  - Add new edge to an every loop except already added loop



$E_{Def}(1,3) = 2$

Add edge to L_3^1 and L_4^3

Add edge to other cycles

for L_2^0

for L_4^2

Simulation results(1)

- **Interleaver construction using PEG algorithm**
  - Local girth distribution (K=510, Rate=0.5)

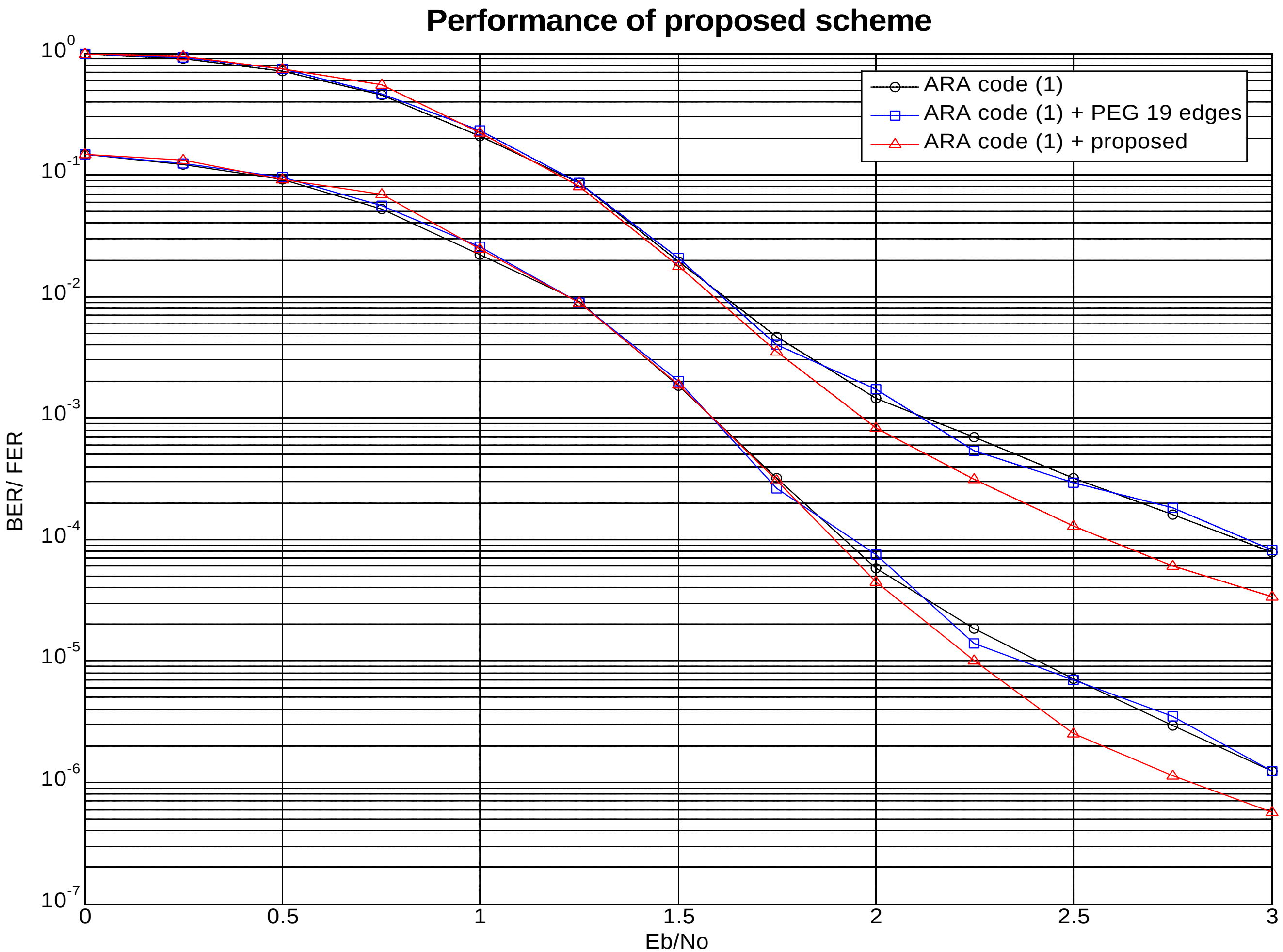
Local girth	4	6	8	10
ARA code (1)	23	247	602	147
ARA code (2)	8	111	456	444

  - Consecutive parity cycle set distribution

	ARA code (1)	ARA code (2)
L_2	4	0
L_3	8	5
L_4	7	2
L_5	2	8

Simulation results(2)

■ ARA code (1)



	Number
L_2	**4**
L_3	**8**
L_4	**7**
L_5	**2**

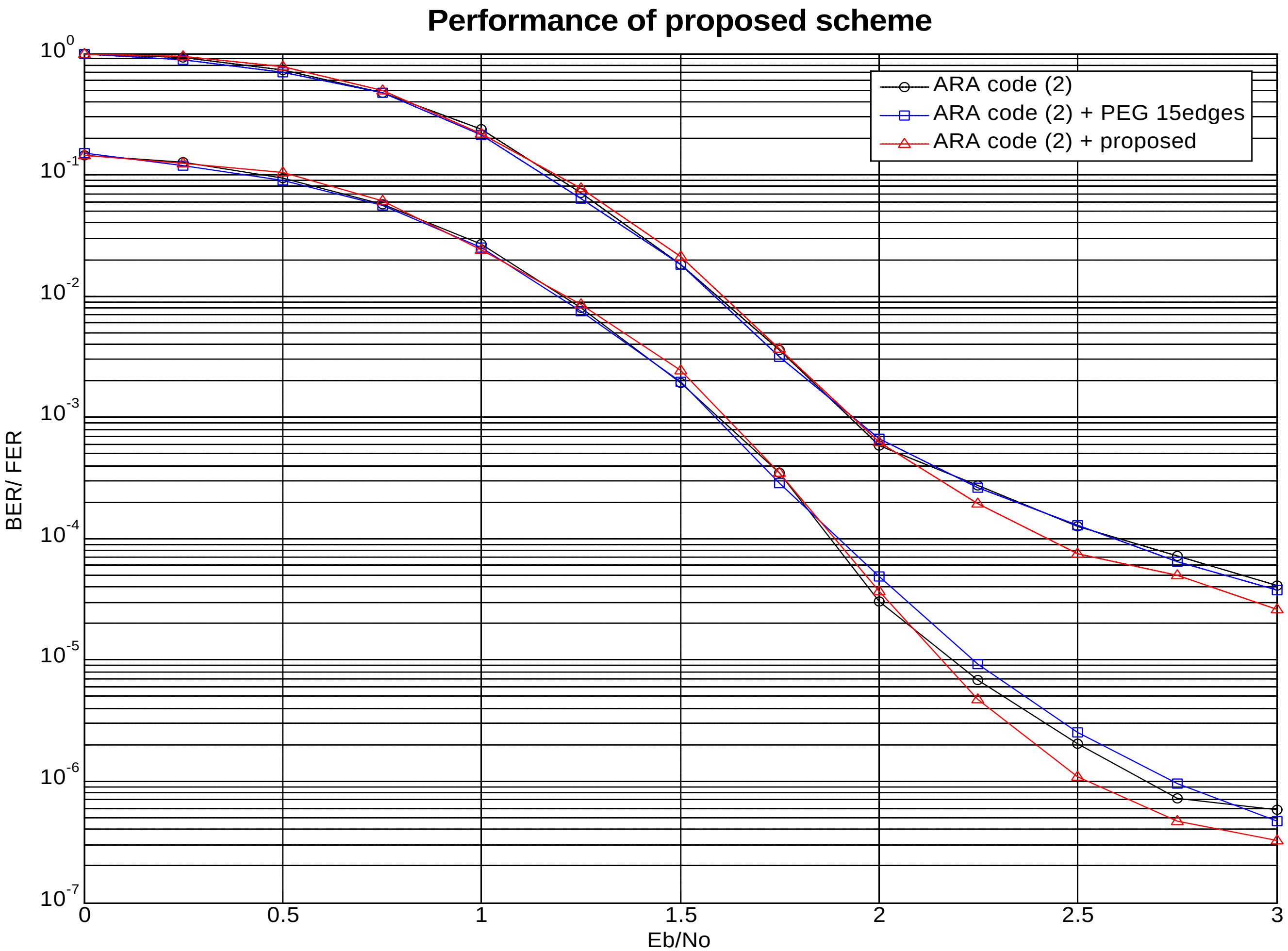
K=510, Rate=0.5

19 edges are added and maximum 1 for each cycle

At FER 10^{-4}, 0.35 dB gain

Simulation results(3)

■ ARA code (2)



	Number
L_2	0
L_3	5
L_4	2
L_5	8

- K=510, Rate=0.5
- 15 edges are added and maximum 1 for each cycle
- At FER 10^{-4}, 0.15 dB gain

Conclusion

- **Improvement of Error floor**
  - Analysis of cycles with some part of the dual diagonal of ARA codes
  - Supplement EMD's with the consecutive parities cycles

- **Some limits**
  - Need enough number of short consecutive parity cycles
  - Cannot provide improvement when appying to a RA codes.

- **Further work**
  - Modification for RA codes and ARA codes with small number of short consecutive parity cycles.

Thank you