WiMAX LDPC codes

Complexity and effectiveness

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WiMAX LDPC codes

Design

For each code rate, a *compressed* encoding matrix is specified by the standard: it is then be expanded to suit a specific code length.

$$\left[\begin{array}{cc||cc} 1 & -1 & 1 & -1 \\ 2 & 1 & -1 & 1 \end{array}\right] \implies$$

$$\implies \left[\begin{array}{ccc|ccc||ccc|ccc} 1 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ \hline 0 & 0 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 1 \end{array}\right]$$

Working modes

IEEE 802.16e WiMAX specification defines various code lengths and rates. All combinations will be further analyzed.

576	672	768	864
960	1056	1152	1248
1344	1440	1536	1632
1728	1824	1920	2016
2112	2208	2304	

Code lengths

1/2	2/3A	2/3B
3/4B	3/4A	5/6

Code rates

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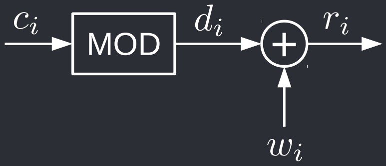
1. Specification
   1.1 Design
   1.2 Working modes
2. Simulation
   2.1 Encoder
   2.2 Modulator and channel
   2.3 Decoder
3. Results
   3.1 Error detection
   3.2 Sum-product iterations
4. Conclusions

Encoder

$$c_i = ENC(u_i) = \left[\begin{array}{c|c} u_i & A\,u_i \end{array}\right] \quad \text{where} \quad \begin{cases} H = \left[\begin{array}{c|c} B & C \end{array}\right] \\ A = C^{-1}B \end{cases}$$

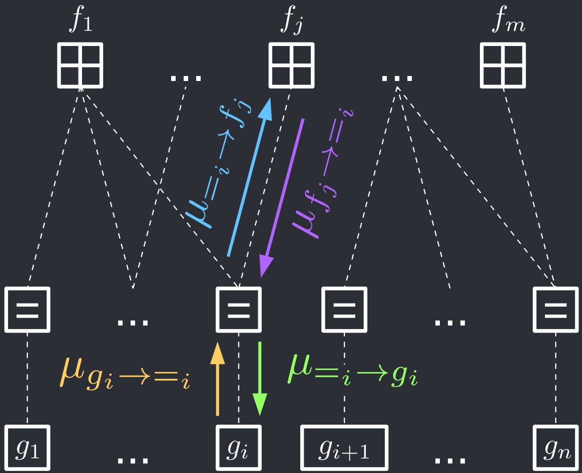
Modulator and channel



$$d_i = MOD(c_i) = \begin{cases} +1 & c_i = 1 \\ -1 & c_i = 0 \end{cases}$$

$$r_i = d_i + w_i \quad \text{where} \quad \begin{cases} w_i \sim \mathcal{N}(0, \sigma_w^2) \\ \sigma_w^2 = \left(2R \dfrac{E_b}{N_o}\right)^{-1} \end{cases}$$

Message passing



FFG of a generic LDPC code

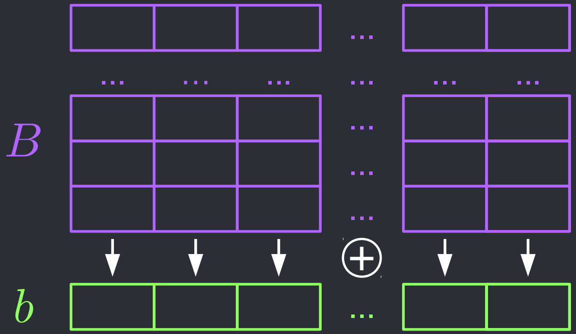
ch channel information

F forward messages

B backward messages

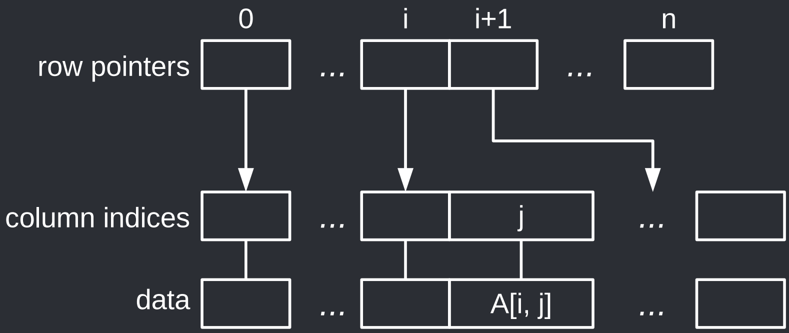
b extrinsic information

Matrix operations



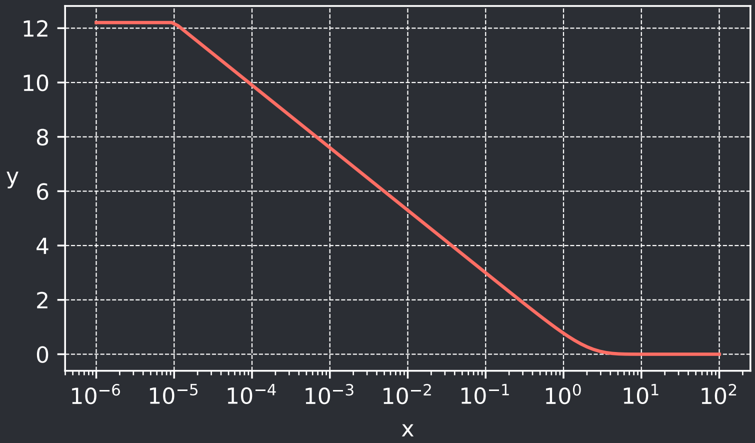
Graph node processing is expressed as simple matrix operations.

Sparse matrix representation



In-memory representation of a generic matrix *A*

Function $\tilde{\phi}$



Function is approximated for small and high values of x

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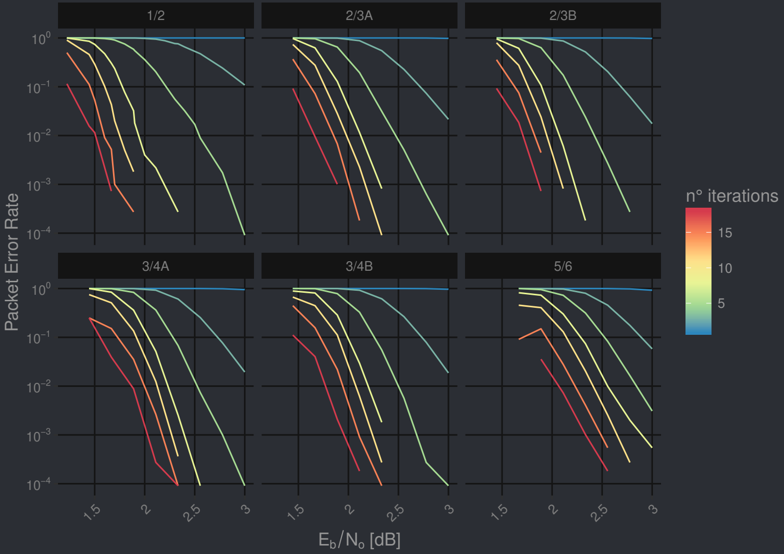
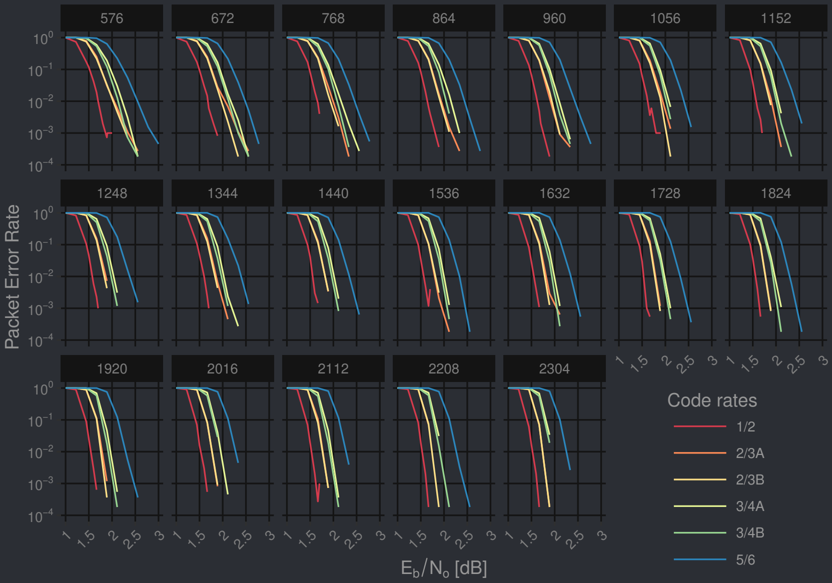
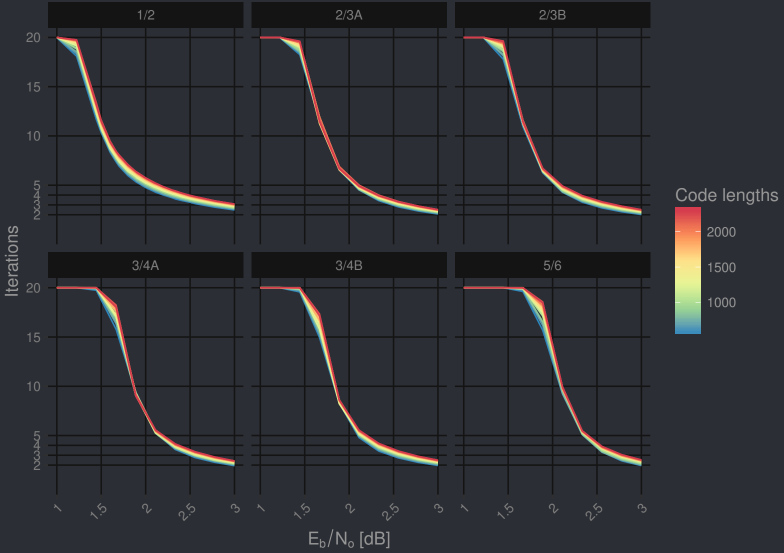
Error detection per code length



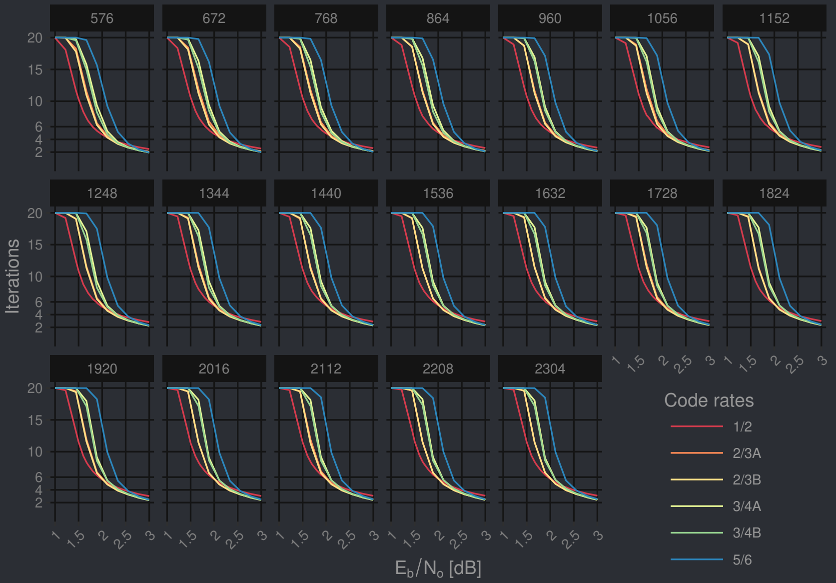
Error detection per code rate



Sum-product iterations per code length



Sum-product iterations per code rate



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Conclusions

- MP performs lots of accesses to messages data structures
- such structures are sparse, since FFG is sparse as well
- stronger codes are easily obtained tuning code rate, while increasing code length gives only a slighter improvement