SDD text proposal for IEEE 802.16m Incremental Redundancy (IR) HARQ with LDPC codes

IEEE 802.16 Presentation Submission Template (Rev. 9)

Document Number:

IEEE C802.16m-08/711

Date Submitted:

2008-07-07

Source:

Guosen Yue, Meilong Jiang, Yuefeng Zhou

E-mail: yueg@nec-labs.com, meilong@nec-labs.com, yuefeng.zhou@eu.nec.com

NEC Group

*<http://standards.ieee.org/faqs/affiliationFAQ.html>

Venue:

IEEE 802.16m-08/024 “Call for Comments and Contributions on Project 802.16m System Description Document (SDD)”

In response to the topic: HARQ

Base Contribution:

IEEE C802.16m-08/711

Purpose:

To discuss and adopt the LDPC codes for IR HARQ for the 802.16m SDD

Chase Combining and Incremental Redundancy HARQ

- Chase Combining and IR HARQ
  - IR HARQ provide higher throughput performance than Chase combing due to the coding gain in addition to the diversity gain.
  - Chase combining has a lower complexity with smaller buffer sizes.

- Both Chase combining and IR HARQ have been included in IEEE802.16e
- We propose continuing to support both Chase combining and IR in IEEE 802.16m as in IEEE 802.16e.

HARQ and FEC

- IEEE 802.16e, the HARQ with Chase combining, IR convolutional codes (CC) and IR convolutional turbo codes (CTC) are supported in both DL and UL transmissions.
- In IEEE 802.16m we propose to continue supporting Chase combining and IR-CC.
- IEEE 802.16m targets for a much higher rate than IEEE 802.16e, the current decoding throughput of CTC may not support such high rate. Also, 802.16m requires significantly improved coverage with respect to 802.16e, it is desirable to consider other coding schemes to achieve these goals.

	HARQ Schemes	IEEE 802.16e	IEEE 802.16m
DL	Chase combining	√	√
	IR Convolutional Codes	√	√
	IR CTC	√	FFS
	IR for other FECs	Not supported	FFS
UL	Chase combining	√	√
	IR Convolutional Codes	√	√
	IR CTC	√	FFS
	IR for other FECs	Not supported	FFS

Table 1: List of Chase combining and IR HARQ schemes supported in IEEE 802.16 and to be supported in IEEE 802.16m [1]

Features of LDPC Codes

- Higher decoding throughput, especially for longer block sizes
- High reliability for low to moderate data rate region or expansion of coverage area
- Low-complexity implementation

Table. Operations count comparison of sub-optimal decoders LDPC and TC decoders.

	LDPC	TC	Complexity of LDPC / Complexity of TC
Algorithm	LBP Min-Sum+Offset	Max Log Map +extrinsic scaling	
Number of Iterations	20	8	
Total cost (R=1/3)	38.5K x 20 = 770K	171K x 8 = 1368K	56%
Total cost (R=1/2)	28.8K x 20 = 576K	171K x 8 = 1368K	42%
Total cost (R=3/4)	20.6K x 20 = 412K	171K x 8 = 1368K	30%

Source: [2] 3GPP TSG-RAN1 #44bis: R1-060874, Intel-ITRI-LG-Mitsubishi-Motorola-Samsung-ZTE

LDPC for IR HARQ

- LDPC codes have been included in IEEE802.16e
  - The code matrices of four code rates are defined. However, they are not rate-compatible.
  - Chase combining HARQ for LDPC is supported in IEEE802.16e
  - IR-HARQ for LDPC codes is not considered in16e.

- In IEEE 802.16m, we propose to support IR HARQ for LDPC codes.
  - To support IR HARQ, rate-compatible LDPC codes should be defined.
    - The RC LDPC codes can be obtained from the LDPC codes defined in 16e by puncturing and extending.
    - Or a set of new RC-LDPC codes are defined in 16m.

QC-LDPC Codes

- Base matrix

$$\mathbf{H}_B := \begin{bmatrix} I(p_{0,0}) & I(p_{0,1}) & \cdots & I(p_{0,L-1}) & I(0) & \mathbf{0} & \cdots & \cdots & \cdots & \cdots & \cdots & \mathbf{0} \\ I(p_{1,0}) & I(p_{1,2}) & \cdots & I(p_{1,L-1}) & I(0) & I(0) & \mathbf{0} & \ddots & \ddots & \ddots & \ddots & \vdots \\ \vdots & \vdots & \vdots & \vdots & \mathbf{0} & \ddots & \ddots & \ddots & \ddots & \ddots & \ddots & \vdots \\ I(p_{J/2-1,0}) & I(p_{J/2-1,2}) & \cdots & I(p_{J/2-1,L-1}) & \vdots & \ddots & I(0) & I(0) & \mathbf{0} & \ddots & \ddots & \vdots \\ \vdots & \vdots & \vdots & \vdots & I(0) & \mathbf{0} & \cdots & \mathbf{0} & I(0) & \mathbf{0} & \ddots & \vdots \\ \vdots & \vdots & \vdots & \vdots & \mathbf{0} & I(0) & \mathbf{0} & \ddots & \ddots & I(0) & \ddots & \vdots \\ \vdots & \vdots & \vdots & \vdots & \vdots & \ddots & \ddots & \ddots & \ddots & \ddots & \ddots & \mathbf{0} \\ I(p_{J-1,0}) & & \cdots & I(p_{J-1,L-1}) & \mathbf{0} & \cdots & \mathbf{0} & I(0) & \mathbf{0} & \cdots & \mathbf{0} & I(0) \end{bmatrix}$$

$\boldsymbol{H}_{BL}$

  - Different code lengths can be obtained by changing the size of circulants.

- Parity-check Matrix

$$\mathbf{M} = \mathbf{Z} \otimes \mathbf{H}_{BL} = \begin{bmatrix} z_{0,0} I(p_{0,0}) & z_{0,1} I(p_{0,1}) & \cdots & z_{0,L-1} I(p_{0,L-1}) \\ z_{1,0} I(p_{1,0}) & z_{1,1} I(p_{1,1}) & \cdots & z_{1,L-1} I(p_{1,L-1}) \\ \vdots & \vdots & \ddots & \vdots \\ z_{J-1,0} I\left(p_{J-1,0}\right) & z_{J-1,1} I\left(p_{J-1,1}\right) & \cdots & z_{J-1,L-1} I\left(p_{J-1,L-1}\right) \end{bmatrix}$$

Z: Mask matrix

Rate Compatible QC-LDPC

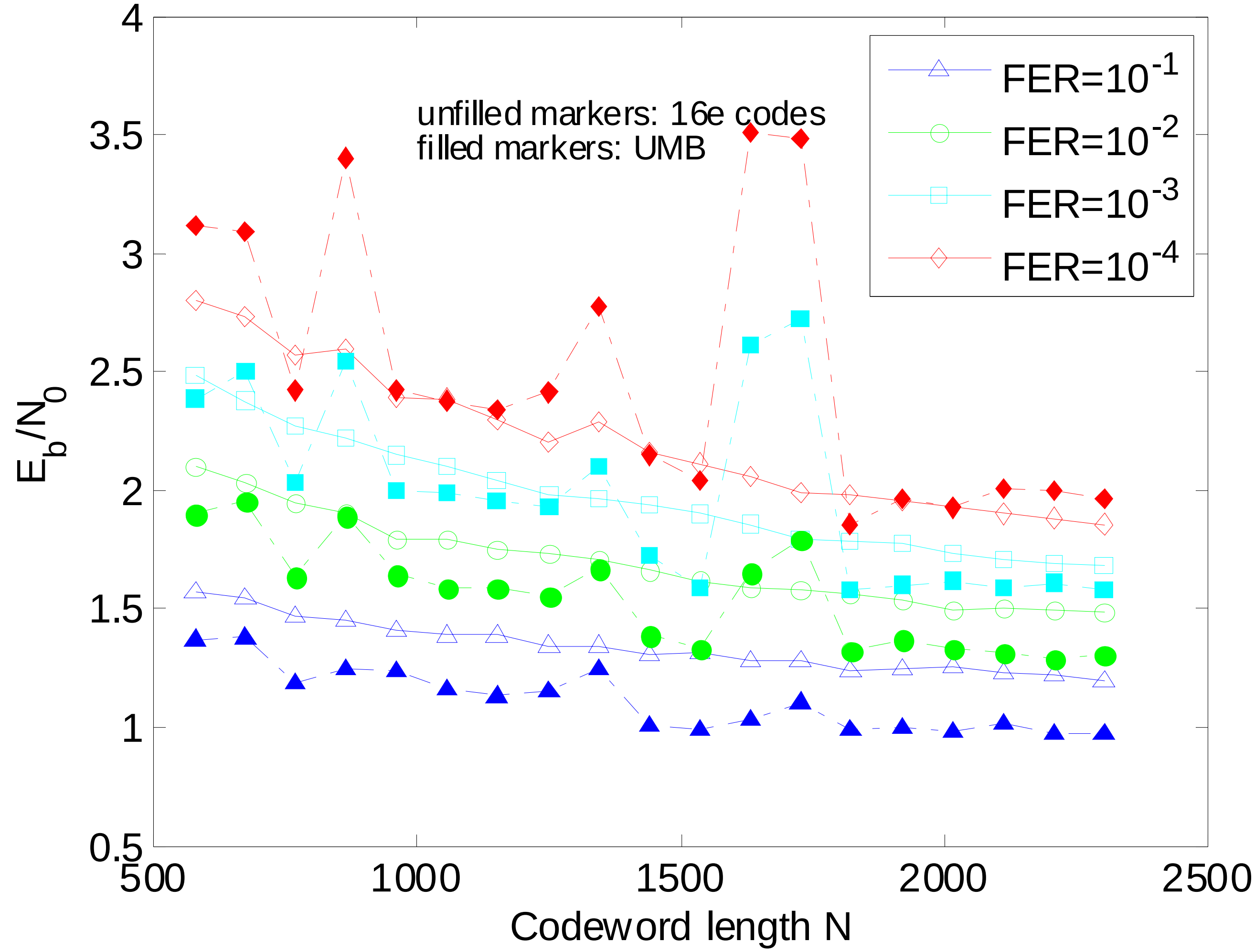
- Rate compatible QC-LDPC codes can be achieve by puncturing.
  - A systematic puncturing approach
    - Based on the code graph, the order of bit puncturing can be designed to achieve better error correction performance in average for all code rates defined IEEE802.16m
    - An interleaver is then formed based on the puncturing order. The interleaver should be included in IEEE802.16m standardization.
    - The coded sequence *r* are first interleaved with the defined interleaver $\underline{r}$. Then the redundancy version can be defined based on interleaved coded sequence $\underline{r}$ similar to IEEE 802.16e approach.

Performance comparisons

- We now provide some performance comparisons of LDPC codes defined in IEEE 802.16e with rate-compatible LDPC codes in AWGN channels.
  - The RC LDPC codes defined in UMB standards [3] are used for performance comparison.
- The performance results are represented by E_b/N_0 required to achieve a certain frame error rate (FER).
  - Four rates: 1/2, 2/3, 3/4, 5/6.
  - Code lengths 576 to 2304.
  - Sum-product decoding algorithm.
- It is seen that well designed RC-LDPC codes perform better than the codes defined in 16e for most code lengths.

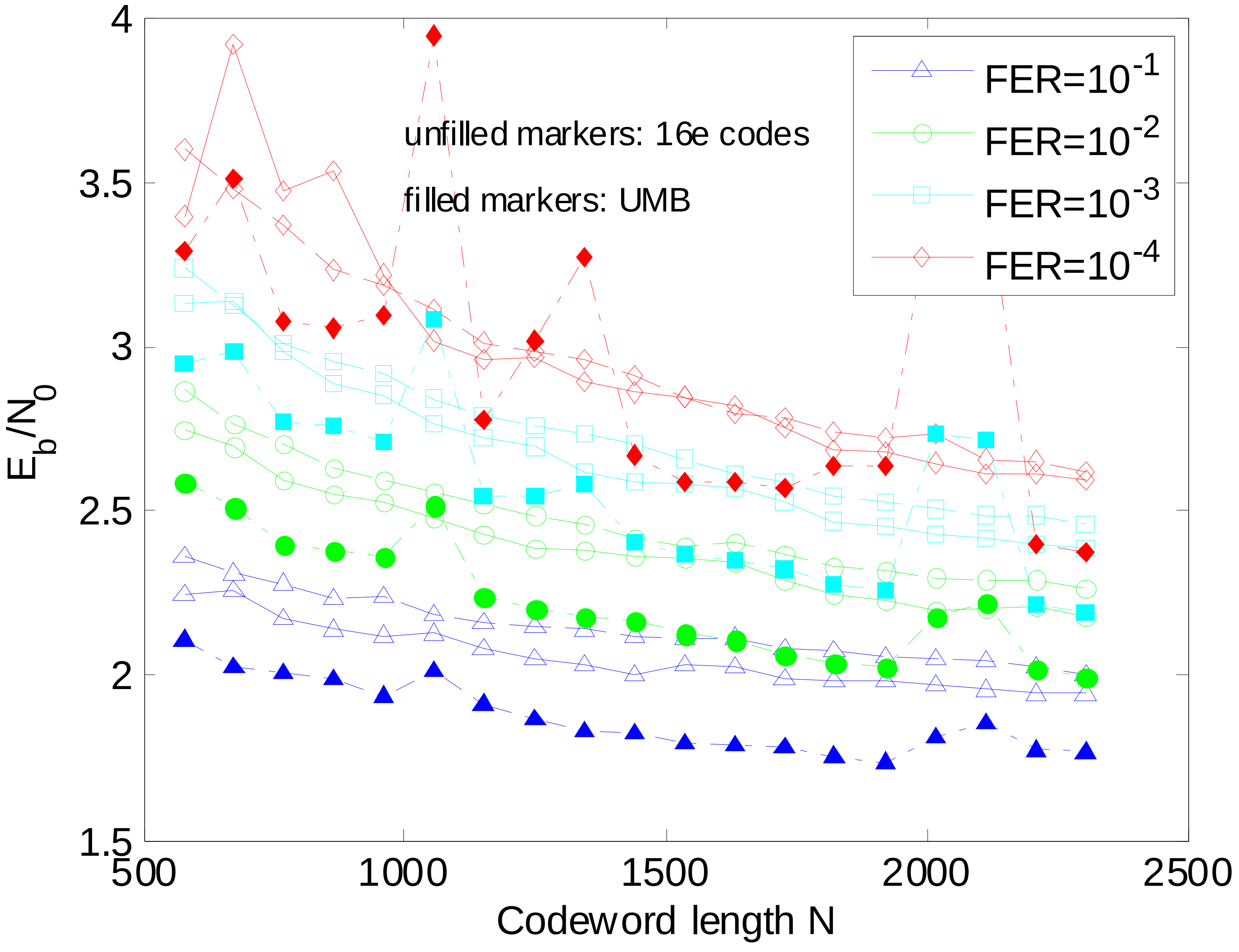
Rate-1/2 LDPC codes

- Solid lines w/ unfilled markers: 16e codes.
- Dash-dotted line w/ filled markers: UMB



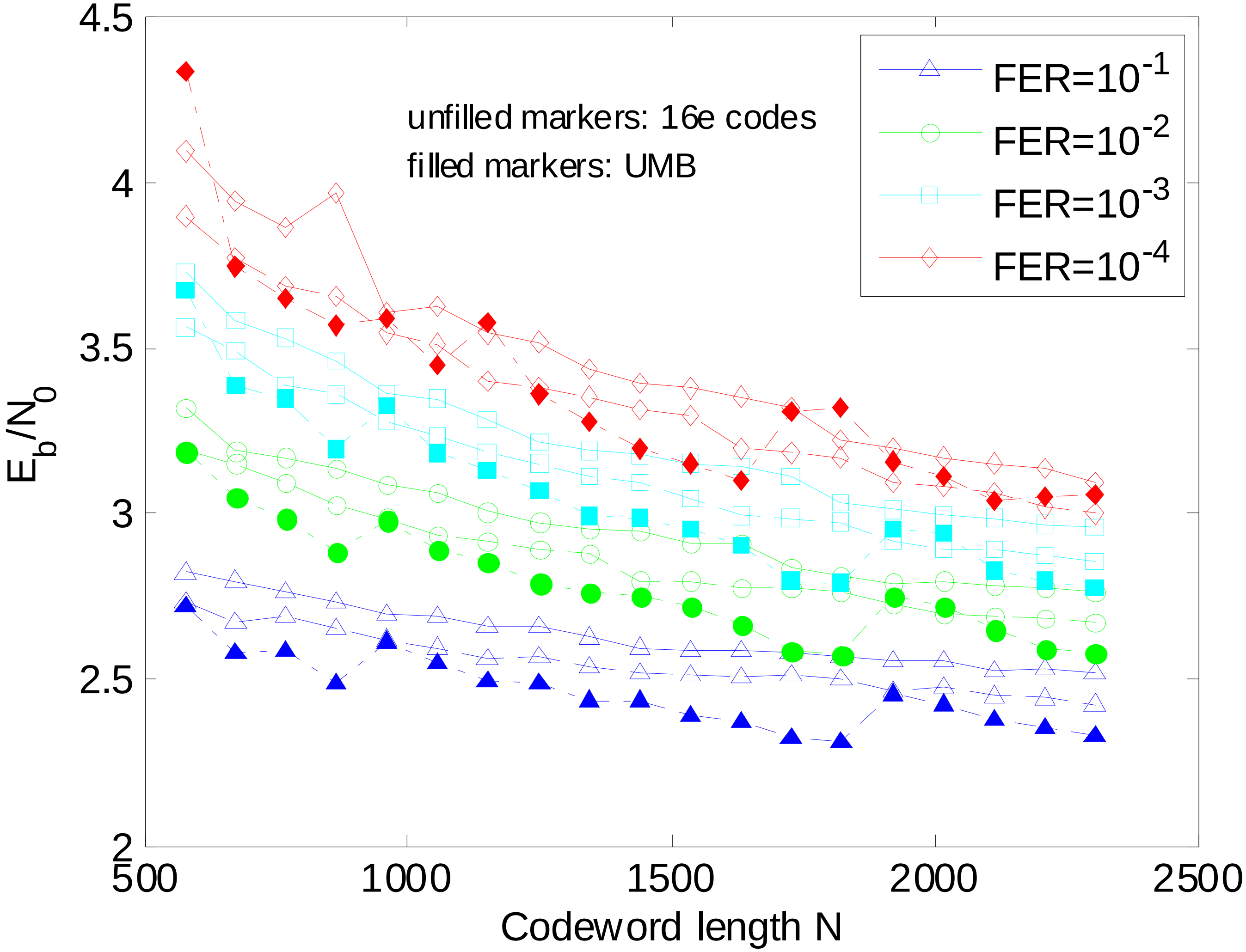
Rate-2/3 LDPC Codes

- Unfilled markers: 16e codes; solid lines: H_A; dashed lines: H_B.
- Dash-dotted line w/ filled markers: UMB



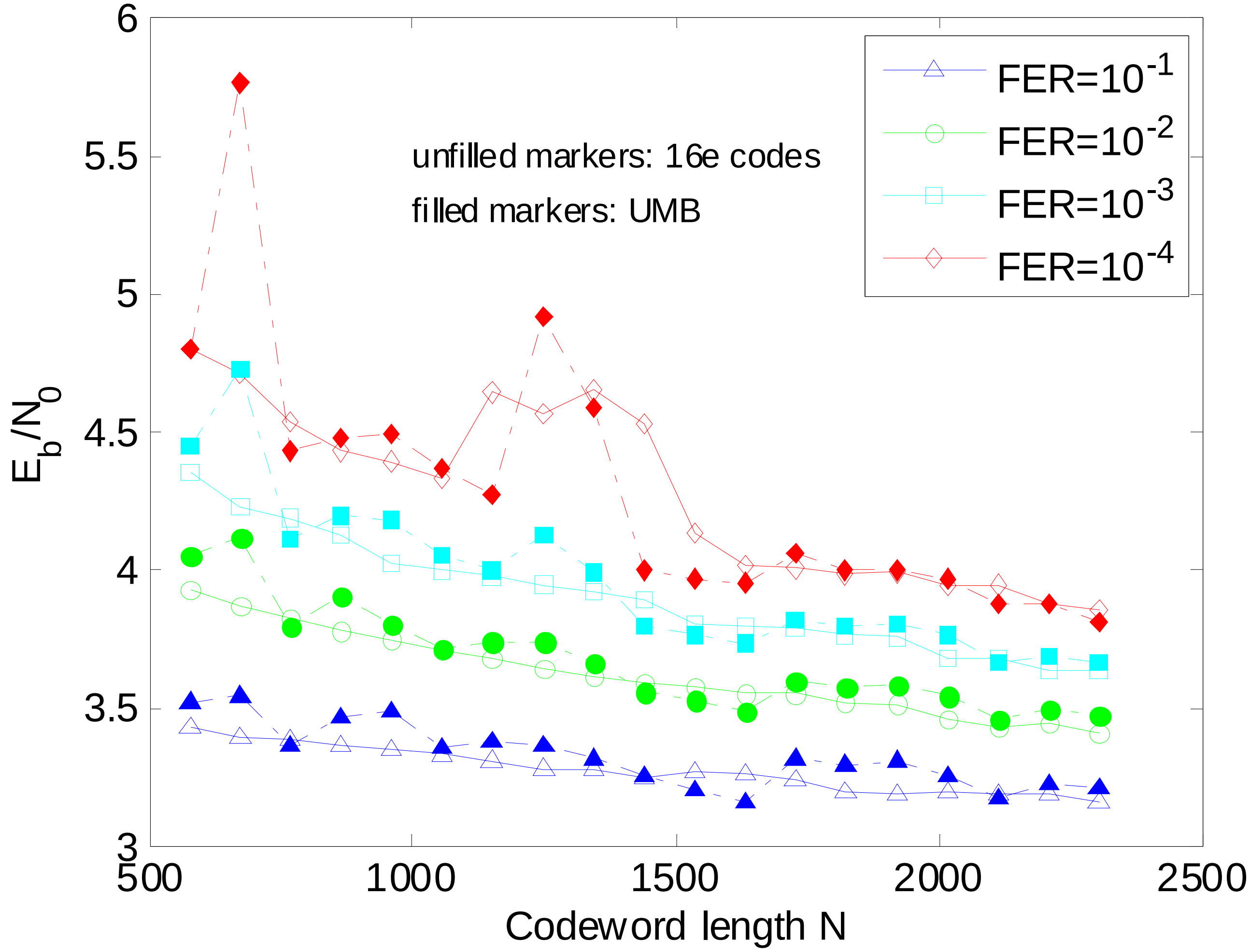
Rate-3/4 LDPC Codes

- Unfilled markers: 16e codes; solid lines: H_A; dashed lines: H_B.
- Dash-dotted line w/ filled markers: UMB



Rate-5/6 LDPC Codes

- Solid lines w/ unfilled markers: 16e codes.
- Dash-dotted line w/ filled markers: UMB



Proposed Text

Insert the following text proposal to the 802.16m SDDs

============== *Start of Proposed Text*==============

IEEE 802.16m supports IR-HARQ for LDPC codes.

IEEE 802.16m defines the rate-compatible LDPC code.

============== *End of Proposed Text*==============

References

[1] IEEE C802.16m-08/334r1, “Hybrid ARQ Protocols and Signaling for DL and UL Transmissions”.

[2] 3GPP TSG-RAN1 #44bis: R1-060874, Intel-ITRI-LG-Mitsubishi-Motorola-Samsung-ZTE

[3] 3GPP2 C.S0084-001-0 v1.088 "Physical Layer for Ultra Mobile Broadband (UMB) Air Interface Specification"