Project	**IEEE 802.20 Working Group on Mobile Broadband Wireless Access** **<http://grouper.ieee.org/groups/802/20/>**	
Title	**LDPC Code Proposal – Technology Overview – Presentation Slides**	
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Re:	IEEE 802.20 Call for Proposals	
Abstract	This document introduces a new coding scheme based on Irregular Repeat Accumulated (IRA) Codes which is proved to be suitable for small packet lengths produced by VoIP-like applications, and thus proposed to be included into Mobile Broadband Wireless Access Systems as an alternative to Convolutional Codes.	
Purpose	For consideration and adoption as a feature for 802.20 standards draft	
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Irregular Repeat Accumulate (IRA) LDPC Code Proposal - for Short Data Block Size

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March 13, 2007

Channel Coding for MBTDD/FDD

- Convolutional coding R-1/3
  - For small data block size, k <128
- Turbo codes, base rate -1/5
  - Parallel Concatenated Convolutional Codes
- Current proposal for consideration:
  - Adopt Irregular Repeat Accumulate Codes in place of the R-1/3 convolutional code

DISTRIBUTION OF PACKET SIZES AS PERCENTAGE OF OVERALL TRAFFIC[1]

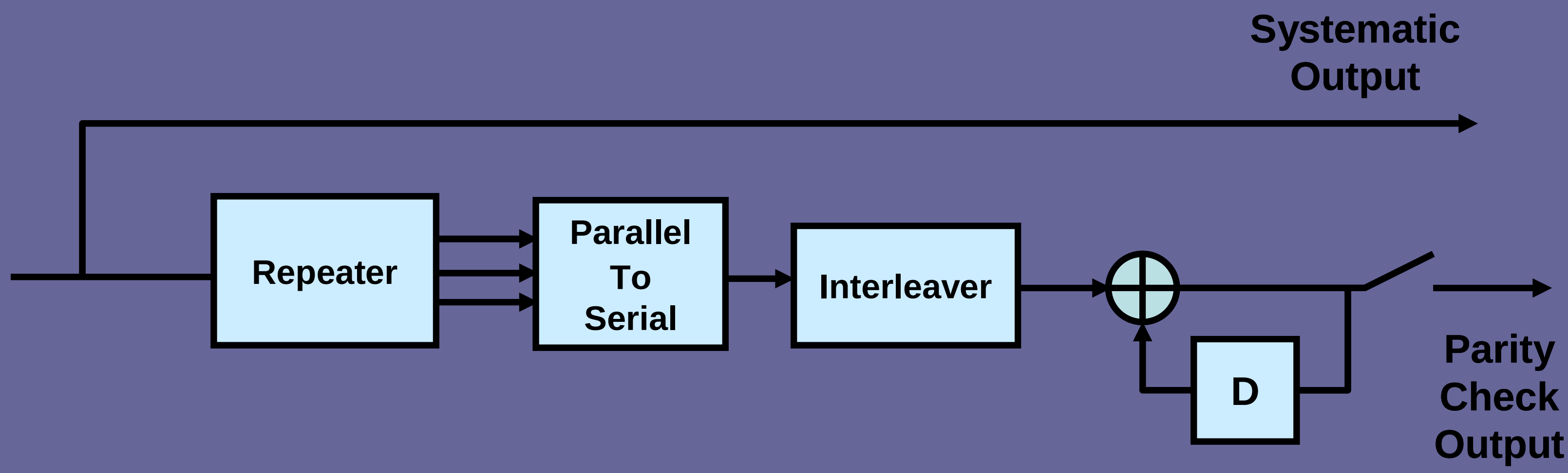
	40 byte	576 byte	1500 byte	Other sizes
HTTP	46.77 %	27.96 %	8,10%	17.17 %
Napster	34.98 %	45.54 %	4.18 %	15.30 %
EMAIL	38.25 %	25.98 %	9.51 %	26.26 %
FTP	40.43 %	18,08%	9.33 %	32.16 %

Source: [1] A. Klemm, C. Lindemann, M. Lohmann, "Traffic Modeling and Characterization for UMTS Networks", Internet Performance Symposium 2001, San Antonio, TX, USA, November, 2001.

Channel Coding of Small Packets

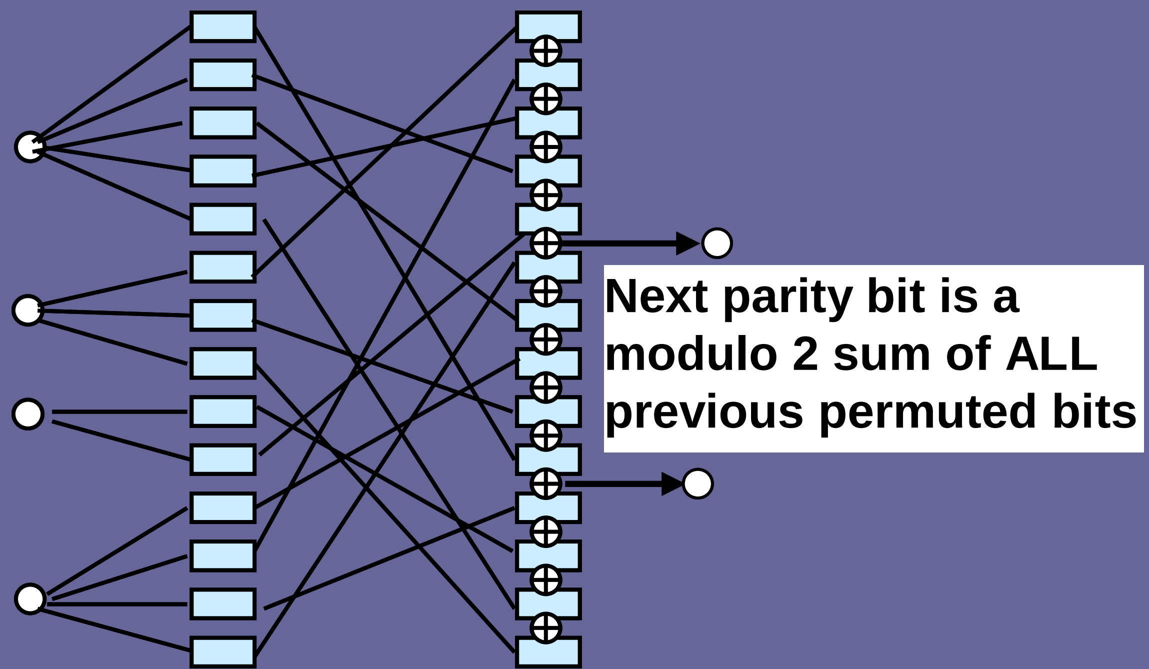
- Irregular Repeat Accumulate Code (IRA)
  - For small packet size, e.g., from 2-40 bytes
  - Example applications:
    - Voice
    - Text messaging
    - Gaming
    - Web browsing
    - ACK
- **Gain of 0.5 dB – 1.0 dB observed from simulation results**

Basic Repeat-Accumulate Encoder Structure



- Serial concatenation of Reptition Encoder and Accumulator, separated by an interleaver
- Accumulator:
  - Rate-1 Convolutional Encoder with polynomial = $\frac{1}{1 + D}$

Tanner Graph of RA Codes



- Subset of LDPC codes
- Variable nodes connecting to Parity nodes via the Edges according to the permutation
- Decode through Message-Passing algorithms (Belief propagation)
- Efficient implementation using parallel architecture
- LDPC codes were discussed in a 2003 Contribution: C802.20-03-02R1 [2]

S-Random Interleaver - Algorithm A

- Degree distribution at the variable node can be defined as:

$$\sigma(y) = \sum_i \sigma_i \cdot y^{i-1}$$

  - where σ_i is the fraction of variable nodes with degree i

- Define:

$$S_i = f(i)$$

- S-Random Algorithm with “S” adapted to the degree of each variable node, i.e., the repetition factor
- For any two nodes m, n belong to fraction σ_i, condition for permutations P(m), P(n):

$$|m-n| < S_i \Rightarrow |\Pi(m) - \Pi(n) \geq S_i|$$

- Requires memory for storage, cannot be computed on the fly

Algebraic Interleaver - Algorithm B

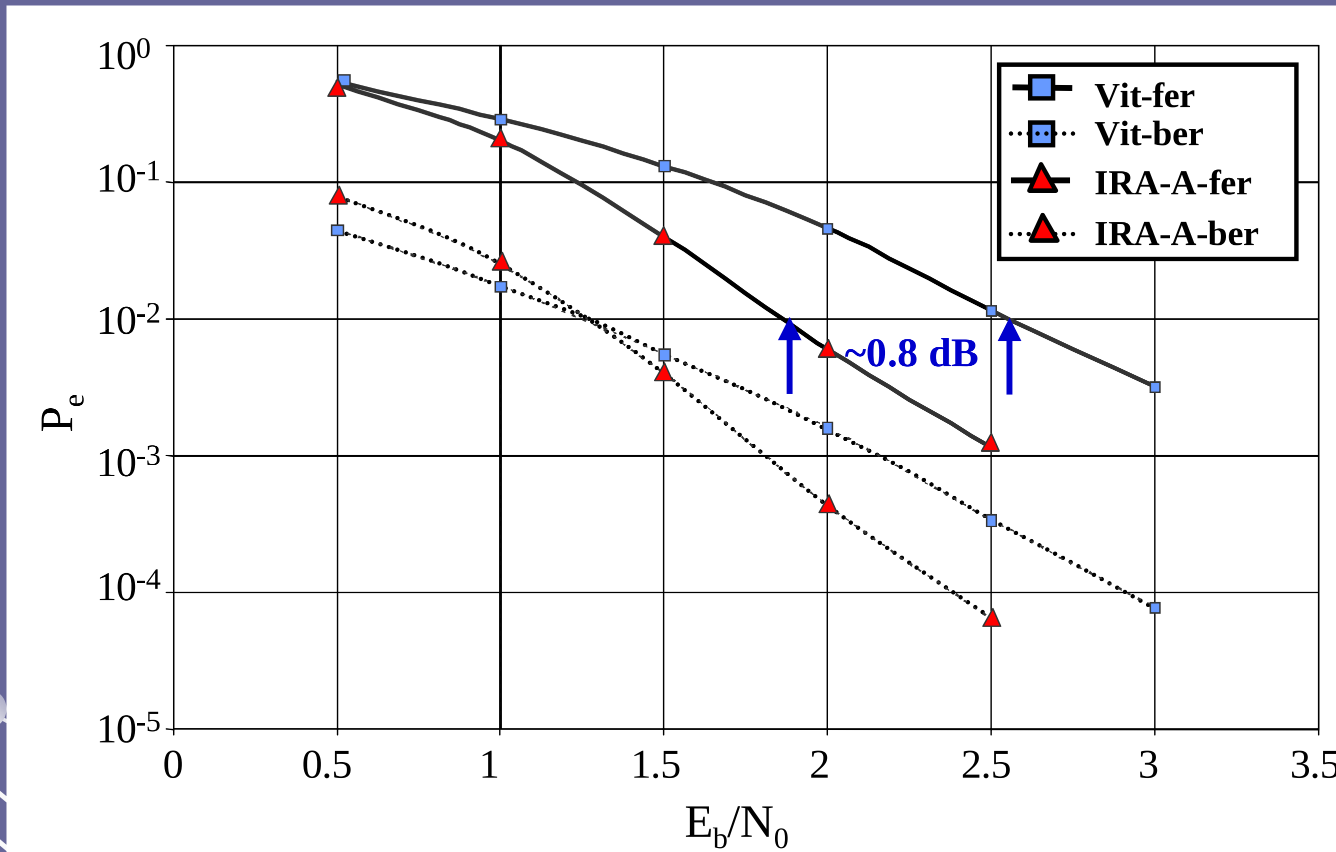
- Circular shifting interleaving
- Advantage: Can be computed on the fly
- Procedure:
  - Randomly drop 24 first numbers (0-23) into rectangular pattern such that only one number shall be placed in each column.
  - Place another number into the column such that the next number in the column is obtained by the following formula,

$$x^{j}_{(i+1)\bmod 4} = (x^{j}_{i} + 72) \bmod 96$$

  - Read the numbers in row-wise order.
  - Check the resulting interleaver with the proposed criteria and define the final group of the interleavers.

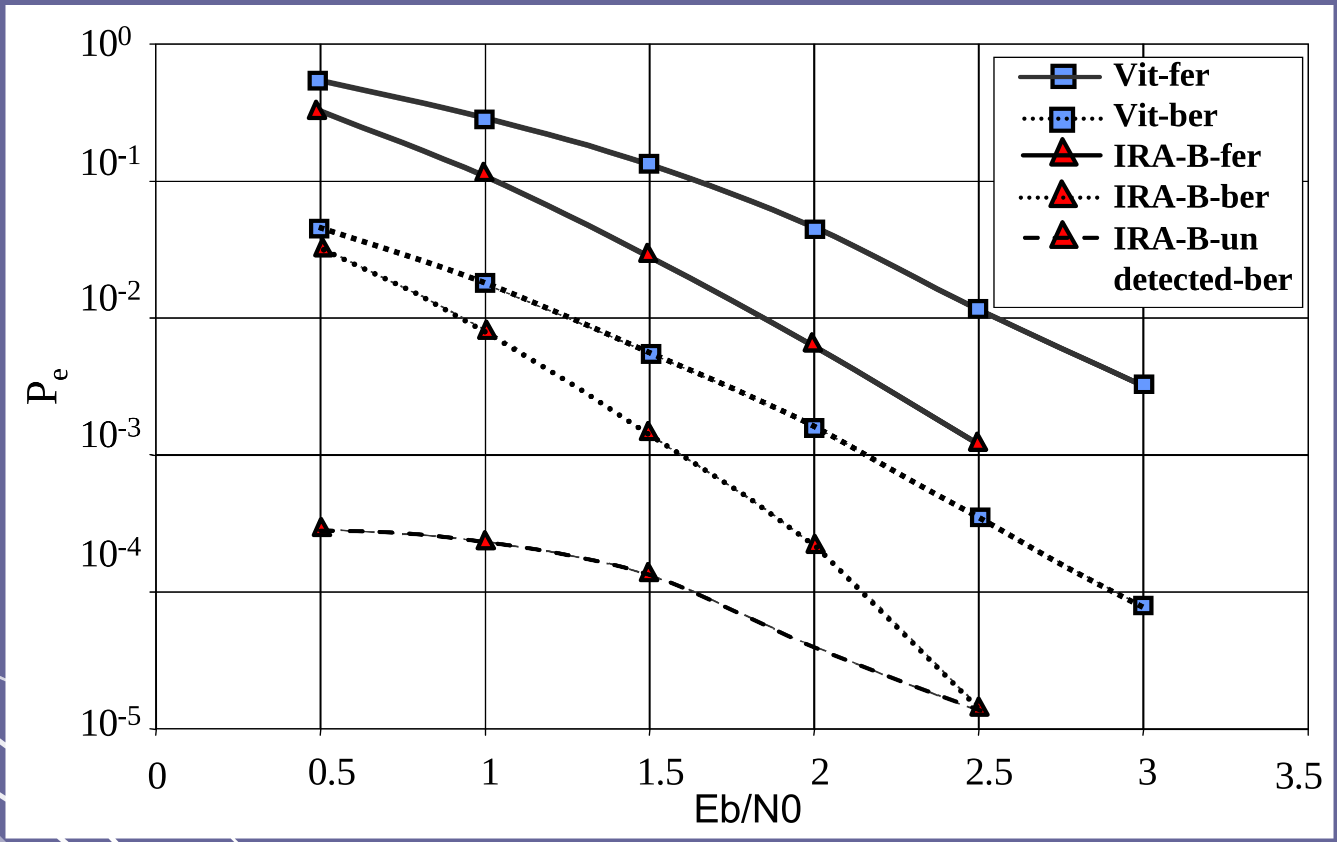
42	89	1	9	40	76	61	19	14	79	45	22	6	50	27	58	48	32	84	63	35	53	71	92
18	65	73	81	16	52	37	91	86	55	21	94	78	26	3	34	24	8	60	39	11	29	47	68
90	41	49	57	88	28	13	67	62	31	93	70	54	2	75	10	0	80	36	15	83	5	23	44
66	17	25	33	64	4	85	43	38	7	69	46	30	74	51	82	72	56	12	87	59	77	95	20

Simulation Results – Algorithm A



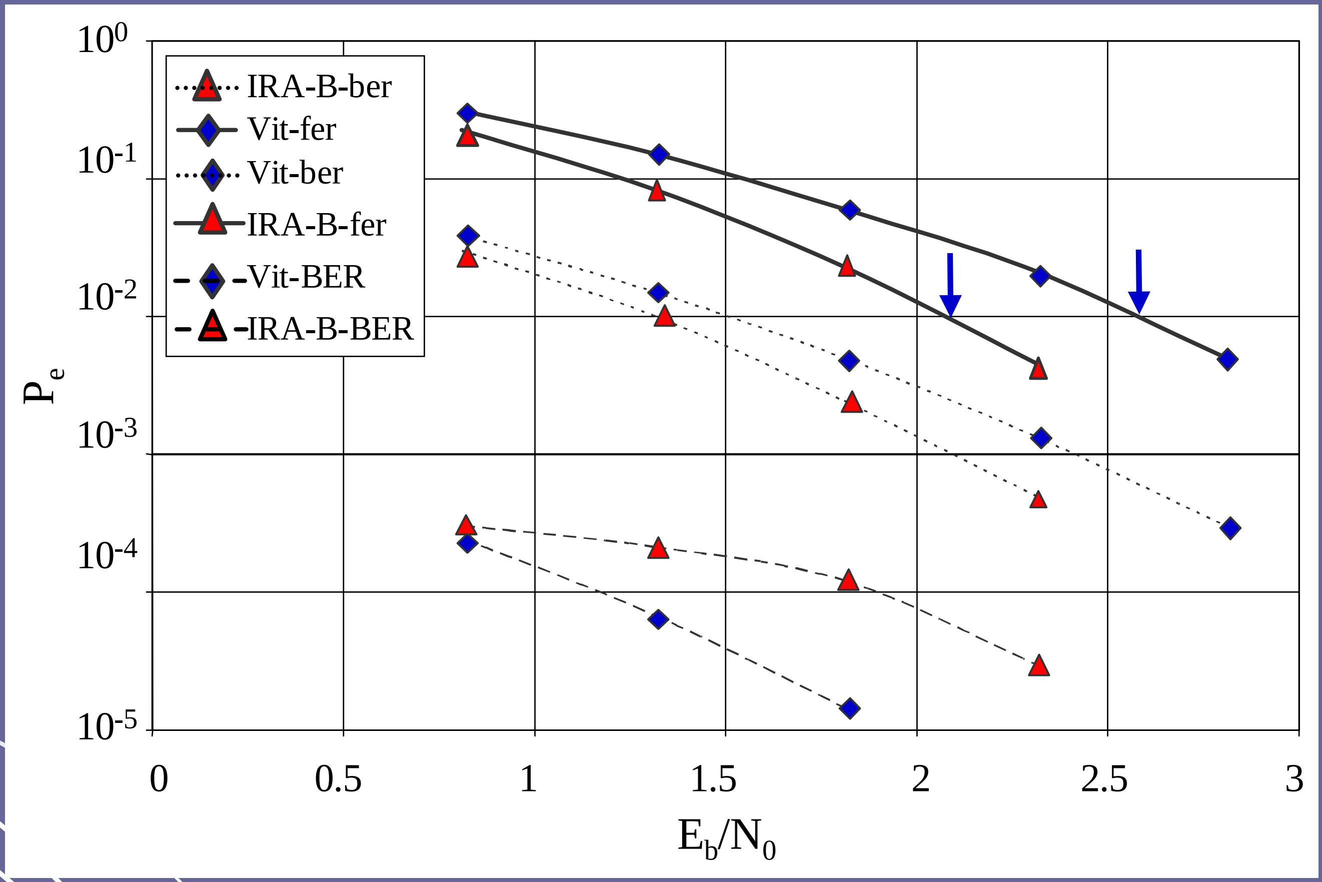
- Full-rate EVRC, 172 bits
- IRA outperforms CC with a gain of 0.8 dB at 10^{-2} frame error rate

Simulation Results – Algorithm B



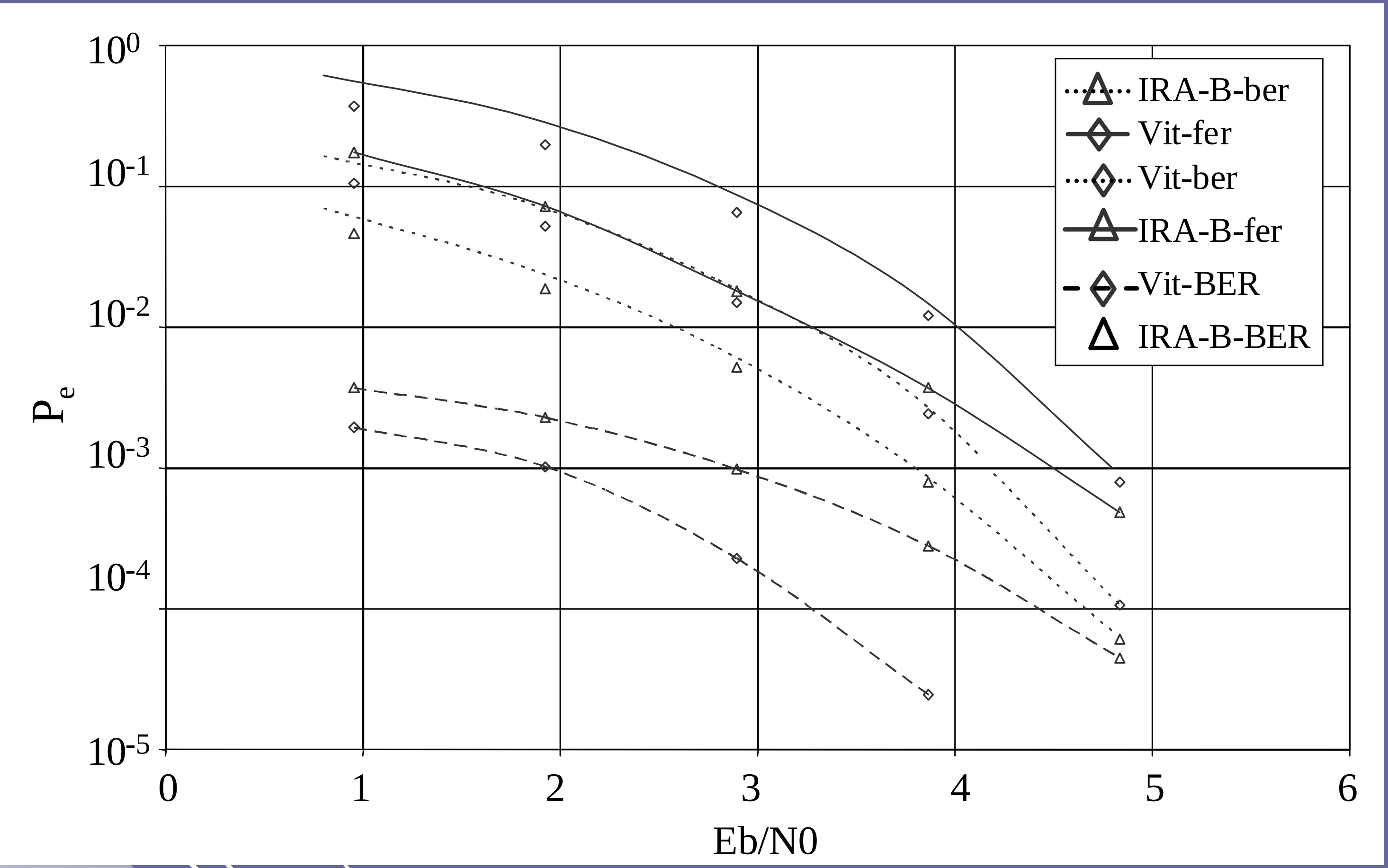
- Full-rate EVRC, 172 bits
- IRA outperforms CC with a gain of 0.8 dB at 10^{-2} frame error rate

Simulation Results – Algorithm B



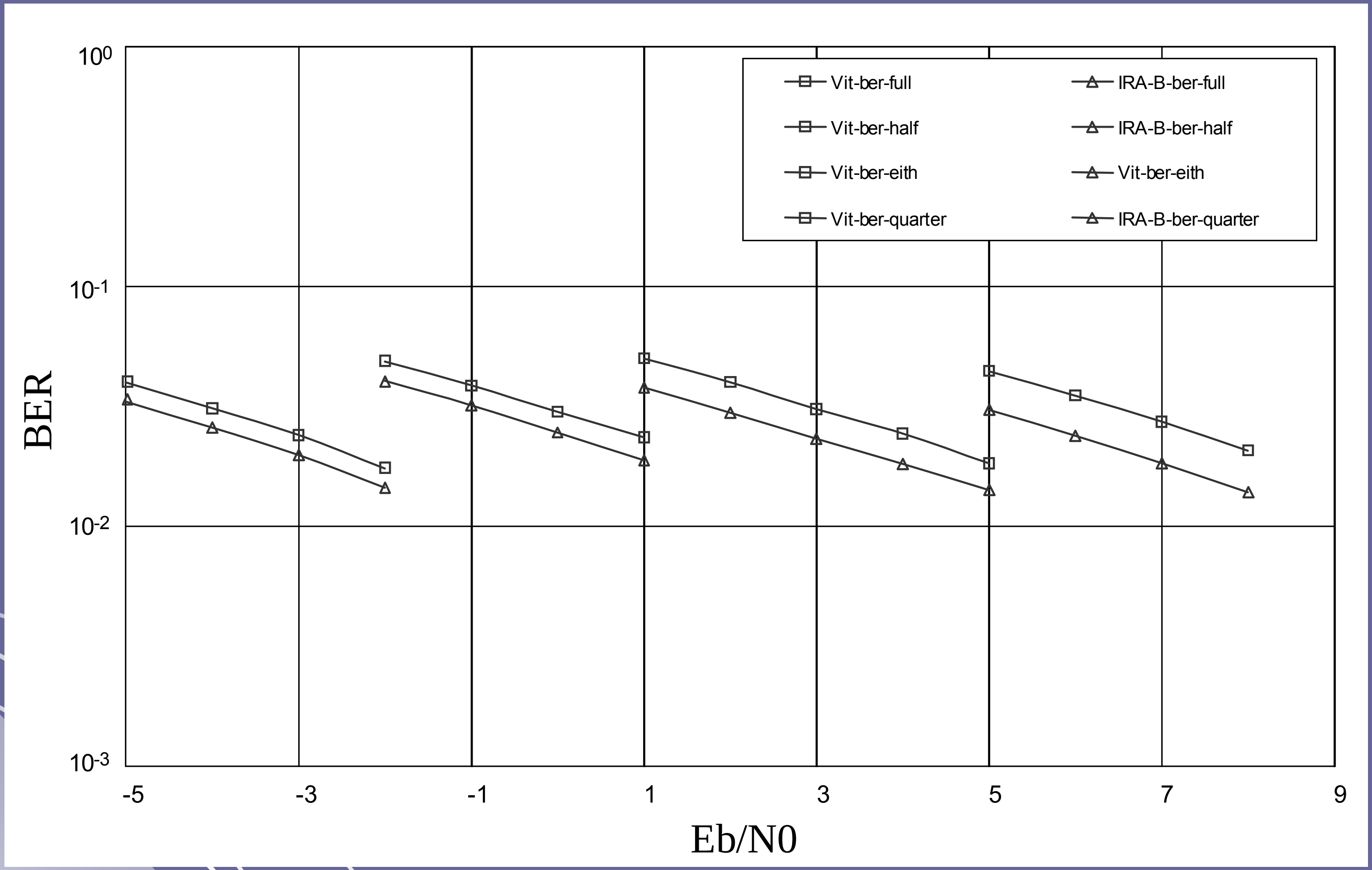
- Half-rate EVRC, 80 bits
- IRA outperforms CC with a gain of 0.5 dB at 10^{-2} frame error rate

Simulation Results – Algorithm B



- Half-rate EVRC, 80 bits
- IRA outperforms CC with a gain of 0.7 dB at 10^{-2} frame error rate

Simulation Results – Algorithm B



- Rayleigh Fading channel, mobile speed: 3 km/h
- IRA outperforms CC with a gain of 1-2 dB at $3x10^{-2}$ bit error rate

Conclusion

- IRA LDPC codes for short packet size outperforms convolutional codes by 0.5 – 1 dB in AWGN at 1% FER
- In Rayleigh fading channel at 3 km/h, IRA LDPC codes outperforms Convolutional Codes by 1-2 dB at ~3% BER
- Consider IRA LDPC codes for adoption as channel encoding scheme in place of the R-1/3 convolutional encoder in the MBTDD/MBFDD proposal

References - I

1. A. Klemm, C. Lindemann, M. Lohmann, “Traffic Modeling and Characterization for UMTS Networks”, Internet Performance Symposium 2001, San Antonio, TX, USA, November, 2001.
2. J. Fan, ‘Soft iterative decoding for mobile wireless communications’, C802.20-03-02R1, Jan 29, 2003.
3. ‘Draft Standard for Local and Metropolitan Area Networks - Standard Air Interface for Mobile Broadband Wireless Access Systems Supporting Vehicular Mobility - Physical and Media Access Control Layer Specification’, IEEE P802.20/D2.1, May 2006.
4. 3GPP2 C.S0014-A, “Enhanced Variable Rate Codec, Speech Service Option 3 for Wideband Spread Spectrum Digital Systems”, April 2004
5. D. Divsalar, H. Jin, and R. J. McEliece, "Coding theorems for turbo-like codes," in 36th Allerton Conference on Communications, Control, and Computing, Sept. 1998, pp. 201--210.
6. H. Jin, A. Khandekar and R. J. McEliece, “Irregular repeat-accumulate codes," Proceedings of the Second International Symposium on Turbo Codes and Related Topics, pp. 18, Brest, France, September 2000
7. G.D. Forney, Jr., "Codes on graphs: normal realizations," IEEE Transactions on Inform. Theory, vol. 47, no. 2, pp. 520 548, Feb 2001
8. Tanner R.M. A Recursive Approach to Low Complexity Codes / R.M. Tanner // IEEE Transaction on Information Theory. – 1981. –Vol. IT-27, № 9. – P.533-547.

References - II

9. MacKay D. Information theory, inference and learning algorithms, Cambridge University Press, New York, NY, 2002. 550 pp
10. S. Dolinar and D. Divsalar "Weight Distribution for turbo codes using random and non-random permutation" JPL Progress report 42-122 pp 56-65, Aug 15,1995
11. 3GPP2 C.S0002-D, "Physical Layer Standard for cdma2000 Spread Spectrum Systems", Revision D, February 13, 2004
12. iLBC Internet Low Bitrate Vocoder, <http://www.vocal.com/ilbc.html>
13. D. Chase, "Code-combining - a maximum likelihood decoding approach for combining an arbitrary number of noisy packets," IEEE Trans. on Commun., vol. 33, May 1985.
14. 3GPP2 C.S0047-0 Link-Layer Assisted Service Options for Voice-over-IP: Header Removal (SO60) and Robust Header Compression (SO61)
15. RFC 3095 - RObust Header Compression (ROHC): Framework and four profiles: RTP, UDP, ESP, and uncompressed, The Internet Society (2001).
16. H. D. Pfister, I. Sason and R. Urbanke, "Capacity-achieving ensembles for the binary erasure channel with bounded complexity," IEEE Trans. on Information Theory, vol. 51, no. 7, pp. 2352-2379, July 2005.
17. T. Lestable, M. Ran et al., "Error Control Coding Options for Next Generation Wireless Systems", White paper from WWRF#17, Heidelberg, Germany, Nov. 2006.