Project	**IEEE 802.20 Working Group on Mobile Broadband Wireless Access** **<http://grouper.ieee.org/groups/802/20/>**
Title	**Irregular Repeat-Accumulate LDPC Code Proposal – Technology Overview**
Date Submitted	**2007-03-05 (March 5, 2007)**
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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
Notice	
Release	
Patent Policy	

I. INTRODUCTION

In the current draft [1] defining the Air Interface of Mobile Broadband Wireless Access Systems, two different mandatory coding schemes are used depending on the information block length to be transmitted over the air.

Indeed, whilst the rate Rc=1/3 Convolutional Code (CC) is employed for short packets whose length is below (or equal) 128 information bits, a rate Rc=1/5 Parallel Concatenated Convolutional Code (PCCC) i.e. Turbo code is preferred for higher packet length.

We thus propose hereafter an alternative optional coding scheme for encoding short packets, by taking advantage of outstanding performances from Irregular Repeat Accumulate (IRA) Codes.

Besides offering a linear encoding complexity w.r.t packet length, these codes inherit some advantages from both Turbo-Codes, and Low-Density Parity Check (LDPC) Codes. They thus induce semi-parallel architectures, resulting in high-throughput decoders, together with being decodable by Message-Passing algorithms only, or by Turbo-like decoding algorithms.

II. BASICS OF IRREGULAR REPEAT ACCUMULATE (IRA) CODES

Repeat Accumulate (RA) Codes [3], together with their enhanced version Irregular Repeat Accumulate (IRA) Codes [4] are part of Sparse Graph Codes family, and as such can be seen as a subset of LDPC Codes. On the other hand, we'll see in the sequel that they can also be seen as a concatenated coding scheme. They were introduced first by Divsalar et al. in [3], and have drawn initial interest due to their simplicity for theoretical studies.

Besides, it can be easily demonstrated that these family of codes offer a linear time encoding, which makes them attractive compared with Turbo-Codes or LDPC Codes [15].

The structure of such RA Codes is depicted in Figure II-1 below, where the concatenated framework is highlighted:

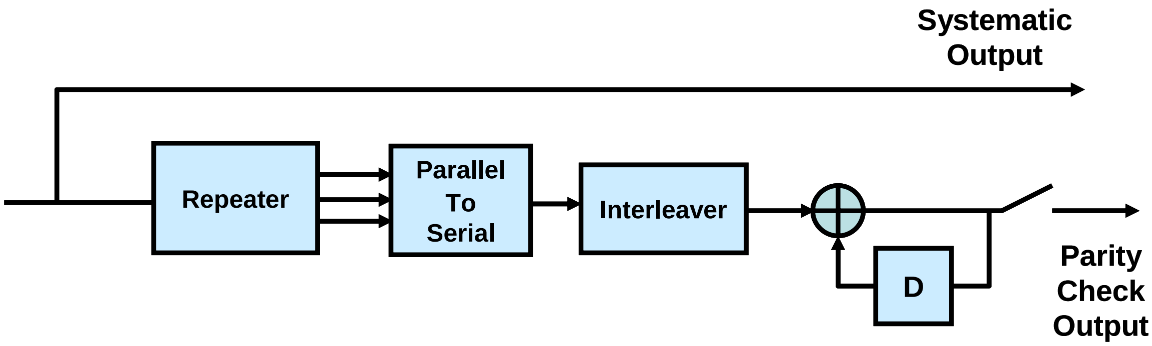

Figure II-1 Repeat Accumulate (RA) Code : Concatenated Structure

Each of the *k* information bits forming the packet to be transmitted over the air, are first repeated *q* times. This can be seen as a repetition code of rate *1/q*. Those n=kq bits are then interleaved and fed into a simple accumulator. This accumulator can be described as a rate-1 convolutional code, with a generator polynomial 1/(1+D).

As such, a RA code is the Serial concatenation of two different coders: repetition code, and convolutional code.

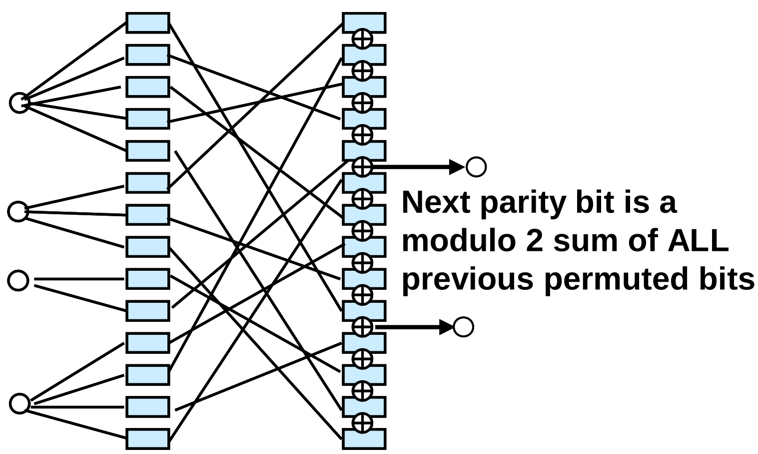

Figure II-2 Tanner Graph of RA Codes

Moreover, such codes as subset of LDPC Codes can also be easily represented by means of their Tanner Graph, cf. Figure II-2: a bipartite graph with bit and parity nodes. This means their decoding can be realized by means of any Message-Passing algorithms, and offer advantageous inherited parallel architecture.

III. INTERLEAVER DESIGN

As outlined in the concatenated structure, the interleaving is a key process whilst designing such IRA codes, together with the distribution of the repetitions.
We are thus going to propose in the sequel two different kinds of interleavers, and evaluate their suitability to the encoding of short packets.

A. Pseudo-Random Interleaver (Algorithm A)

We reuse here the 'S-Random' algorithm [6], by adapting the 'S' factor w.r.t. the repetition factor of each variable node (Irregular Code).
Let's define the following polynomial: $\sigma(y) = \sum_i \sigma_i \cdot y^{S_i}$.

where σ_i means a fraction of indices, such that, for any two indices *m*, *n* from this fraction, the following condition is fulfilled:

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

where $\Pi(m)$, $\Pi(n)$ are the resulting indices after permutation.

Note that some i S could be more than N / 2 but all i S must be more than i . A disadvantage of the approach is that the interleaver requires memory to store numbers and it is not possible to design it on fly.

B. Algebraic Interleaver with induced Randomness (Algorithm B)

We propose here to use an Algebraic Interleaver which can be generated on the fly, and can be fully defined by only few parameters. We particularly focus here on the circular shifting interleaver even though many other techniques can be found in [8].

IV. SIMULATION RESULTS

In order to illustrate our results, we've decided to evaluate the two proposed schemes, namely IRA-A (Pseudo-Random), and IRA-B (Algebraic) codes, for the particular transmission of short packets generated by an EVRC vocoder. This is an opportunity indeed to draw attention on VoIP-like applications. Such vocoder will produce 3 different kinds of information block length, respectively 172, 80 and 16 bits (cf. [9]).

As a result, our evaluation will be compared with a Convolutional Code, since this is mainly the coding scheme in use for such lengths.

With a target FER of 1%, the Algorithm A (IRA-A) ends up with 0.8dB improvement compared with the convolutional code (cf. below Figure IV-1).

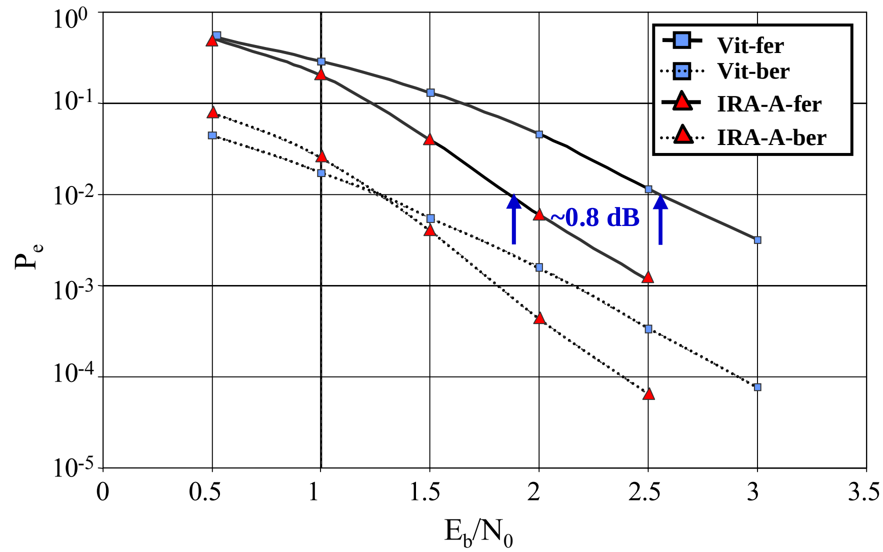

Figure IV-1 Algorithm A, BER/FER Vs Eb/N0: Full Rate EVRC (172 bits)

Now, for the same information length, 172 bits, the second code IRA-B results in 0.5dB gain w.r.t. the convolutional case (Figure IV-2).

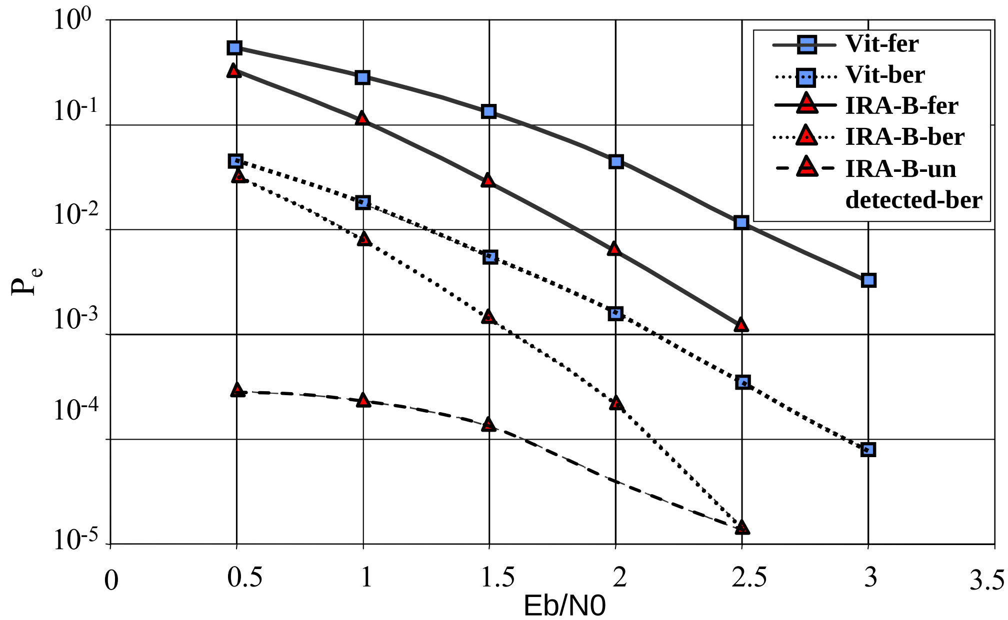

Figure IV-2 Algorithm B, BER/FER Vs Eb/N0: Full Rate EVRC (172 bits)

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