A Hybrid ARQ Scheme Using LDPC Codes with Stochastic Decoding
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ABSTRACT

• Use the stochastic decoding algorithm to decode LDPC codes in the hybrid ARQ scheme.
• Stochastic decoding is a low hardware complexity and energy efficient approach to implement iterative LDPC decoders.
• Stochastic decoding results in improved error rates and less latency than other algorithms in the HARQ system.
• Provide a criterion to efficiently allocate decoding cycles to the decoding attempts in HARQ system to achieve better performance.

HYBRID ARQ

• Forward Error Correction + Automatic Repeat reQuest.
• Type-I stop-and-wait ARQ.
• Employ Chase combining.
• Assume constant energy for each transmission and the feedback channel is noise-free.

LOW-DENSITY PARITY-CHECK CODES

• An error correcting code provides near-capacity performance.
• Decoded by a method based on iterative belief propagation, e.g., the Sum-Product Algorithm (SPA) or the Min-Sum Algorithm (MSA).
• Longer codeword length gives better performance; however, it increases the complexity of interconnection network.

\[ H = \begin{bmatrix} 1 & 1 & 0 & 1 & 0 & 0 \\ 1 & 1 & 1 & 0 & 1 & 0 \\ 0 & 0 & 1 & 1 & 1 & 1 \\ 0 & 1 & 1 & 1 & 1 & 0 \end{bmatrix} \Rightarrow \begin{bmatrix} 1 \& 0 \& 0 \& 1 \& 0 \& 0 \end{bmatrix} \]

STOCHASTIC LDPC DECODING

• Use bit sequence to represent the probability message.

\[ p_1 = 0.8 \Rightarrow \frac{1111111100}{1010111111} \]

• Transmit the message over each edge in bit-wise fashion on a single wire.
• Simple bit operations can operate at high clock rate.
• Structure of nodes in stochastic LDPC decoders, Variable node:

\[ P_a \quad J \quad P_b \]

Check node:

\[ P_a \quad K \quad P_b \]

\[ P_c = P_a (1 - P_b) + (1 - P_a)P_b \]

COMPARISON AND ANALYSIS

• Compared with the SPA and MSA, stochastic decoding algorithm gives the lowest Frame Error Rates (FERs).
• Lower FERs at previous decoding attempts in HARQ imply lower the overall error rates, less retransmission numbers.

PERFORMANCE OF HARQ

• Error rates and latency of HARQ-2 using LDPC code.

DISTRIBUTION OF DECODING CYCLES

• Numbers of decoding cycles in different decoding attempts are not required to be the same.
• The WiMAX (1056,528) LDPC code in the HARQ system with 600 available cycles.

\[ D_{i,\text{max}} < D_{j,\text{max}} \quad \text{for } 1 \leq i < j < N. \]

• For HARQ system with $N$ maximum decoding attempts, let the number of decoding cycles $D_{i,\text{max}} < D_{j,\text{max}}$, for $1 \leq i < j < N$.

\[ \Rightarrow \text{lower error rates,} \]

\[ \text{less decoding latency.} \]