Lowering the power consumption of resilient next-G communications and storage devices

This invention improves the accuracy and efficiency of data transmission and storage (e.g., 5G, WiFi, flash memories) by selectively filtering data errors during decoding, leading to better performance than existing methods without requiring extensive hardware redesign.

Innovation & Solution

Low-density parity-check (LDPC) codes are a type of error-correcting code used in various applications like cellular data, WiFi, and data storage. These codes rely on a decoding algorithm, commonly a simplified version called the min-sum algorithm, to ensure accurate information transfer. While effective, this algorithm and its variants often apply a uniform attenuation or offset, reducing message values uniformly during processing. This invention introduces a novel approach by selectively attenuating or offsetting messages based on a simple threshold. This method adds minimal complexity while significantly enhancing the decoder's performance.

The invention's differentiation lies in its ability to overcome inherent weaknesses in LDPC code design. Traditional methods often get stuck correcting specific error patterns. Addressing this limitation typically requires complex hardware redesigns or expensive post-processing. This selective attenuation technique effectively mitigates these error-trapping scenarios without demanding significant modifications to existing hardware or code designs. This advantage makes it particularly valuable for applications bound by industry standards or seeking cost-effective performance enhancements.

Background & Problem

Low-density parity-check (LDPC) codes play a crucial role in modern communication and data storage systems, ensuring reliable transmission and retrieval of information across various applications like cellular networks, Wi-Fi, optical communication, and magnetic recording. These codes work by introducing redundancy in the data, allowing receivers to detect and correct errors introduced during transmission or storage. The increasing demand for faster, more efficient, and reliable data handling necessitates constant improvements in LDPC decoding algorithms.

Current LDPC decoding methods predominantly relies on the min-sum algorithm and its variants due to their relatively lower implementation complexity. However, these approximations introduce inaccuracies in message passing during the decoding process, leading to performance degradation compared to the optimal but computationally expensive belief propagation algorithm. Existing min-sum variants attempt to mitigate these inaccuracies using uniform attenuation or offset, applying the same reduction to all message values. This approach fails to address the specific error patterns that can trap the decoder, limiting the decoder's effectiveness and overall performance.

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Competitive Advantage

- **Adaptive Message Attenuation:** Unlike existing implementations that use uniform attenuation or offset, such as the standardized Min-Sum algorithm used in IEEE 802.11 wireless communication standards, our invention selectively attenuates messages, which allows for more precise error correction across various signal-to-noise ratios without the need for complex hardware modifications.
- **Improved Error Correction Performance:** Our invention overcomes weaknesses in the code design that can trap decoders using traditional LDPC decoding algorithms, such as those employed in 5G and Wi-Fi communications. This leads to better error correction performance compared to standard Min-Sum algorithms and their uniform attenuation variants.
- **Low Implementation Complexity:** The new decoding method introduces a simple threshold comparison mechanism for selectively attenuating messages, which avoids the need for extensive redesign and modification of hardware. This can be a significant advantage over alternative approaches such as restructuring the entire code design, which is not feasible in cases where an industry standard (e.g., IEEE standards) must be followed.
- **Cost-Efficiency:** The proposed decoder can reduce implementation and usage costs associated with power, area, and speed, which makes it a competitive alternative to the more computationally intensive Decoding algorithms like the Belief Propagation algorithm that are typically used for optical communication and space and satellite communication but may consume more resources.
- **Applicability to New and Existing Standards:** The design of our invention allows for seamless integration with both new and existing wired and wireless communication standards, as well as data storage applications, such as flash memories and magnetic recording. This contrasts with other solutions that may require new standards or are not backward compatible with existing technologies.

Applications

- 5G and 6G cellular communication
- WiFi data transmission
- Optical communication systems
- Flash memory storage
- Magnetic data recording

Benefits

- Reduced implementation and usage costs (power, area, speed) compared to standard LDPC decoding algorithms
- Improved error correction performance across all signal-to-noise ratios
- Overcomes weaknesses in code design that trap traditional decoders without requiring code redesign
- Low complexity implementation compared to alternative approaches for similar performance gains
- Applicable to new and existing wired/wireless communication and data storage applications

Patent & Application

- **Patent US 11,962,324 B1** Threshold-based min-sum algorithm to lower the error floors of quantized low-density parity-check decoders
- **Utility Application 18/612,919**

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