UDC 621.391.14

DIFFERENT APPLICATIONS AND IMPLEMENTS OF THE HAMMING PRODUCT CODES

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Received February 28, 2022

Abstract. Hamming code are a family of linear error-correcting codes, which can detect one-bit and two-bit errors, or correct one-bit errors without detection of uncorrected errors. Hamming product codes are an improved variety of Hamming codes. This paper briefly describes Hamming product codes and compares the different implementations.

Keywords: Hamming codes, product codes, Multi bit error, Extended hamming product code.

Introduction

Hamming Product Code, or Product Code in brief, is a serially concatenated linear block code with two or more component codes. It is a "long" code made by a simple combination of "short" codes, and it can be decoded by a simple component-wise decoding [1].

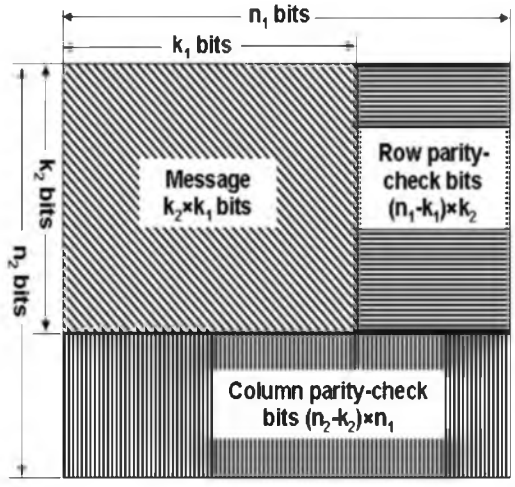

Figure 1. Construction of two-dimensional product codes [2]

As shown in Figure 1, a block of product codes contains a data matrix of size $k_1 \times k_2$, row parity bits of size $(n_1 - k_1) \times k_2$, and column parity bits of size $(n_2 - k_2) \times n_1$. The row parity bit consists of the parity value of the data bits in the row, and the column parity bit consists of the parity value of the column (either the data bits or the row parity bit). If the rows and columns and their corresponding parity checks have minimum Hamming distances d_1 and d_2, respectively, then in theory, the minimum Hamming distance of this two-dimensional product code is $d_1 \times d_2$.

A product codes constructed in this way can achieve a better effect, also in the meantime, can have an acceptable performance overhead. Years of research have led to a variety of implementations, including hardware and software.

Among the many implementations, the hardware-based implementations appear to be more useful and attractive. Because the hardware-based implementation has a stable and superior performance.

These hardware-based implementations go beyond simply implementing the algorithm and go on to incorporate other techniques to improve overall performance.

Applications

The simplicity of Hamming code makes it suitable for applications with a higher sensitivity to performance overhead and latency. The ability to correct multiple random and burst errors makes the product code a good choice for a lightweight on-chip interconnect error correction solution.

Mixing multiple technologies can lead to more gains than just improved algorithms. The product code is often used in conjunction with other error control techniques to improve its overall performance and reliability. Common technology portfolios include automatic repeat requests (ARQ), forward error correction (FEC), and hybrid ARQ (HARQ).

At the same time, the product code can also be applied to scenarios requiring high-speed coding and decoding, such as flash memory error correction. The experiments show that the coding efficiency is 11 % and the actual coding efficiency is 12,6 % when the effective data two-dimensional structure in flash memory system is 1024×128 with two-dimensional Hamming code structure. The encoding speed and decoding speed reached 102 Gbps, which is suitable for high-speed storage system [3].

Codec Design

Common application scenarios where encoders and decoders use different designs. In addition, the codec also integrates other error correction mechanism. Most designs will use semaphores to communicate between the encoder and decoder. Due to the design of the product code, the coding and decoding process includes repetitive operations, so it is also a common design to add cache and logic control modules while reusing a single codec unit.

A design with multiplexed row or column codecs applying types-II of HARQ is illustrated in Figure 2. In this design, rows and columns are processed separately and the results are finally merged by a MUX and sent. The design also builds the communication structure between the encoder and the decoder. With this communication structure, the decoder can control the encoder to perform actions in case of unrecoverable errors. Because the communication between the codecs of this design includes at least two signal quantities (ACK/NACK), the design uses a triple redundant communication line design in order to avoid communication failures between the encoder and decoder.

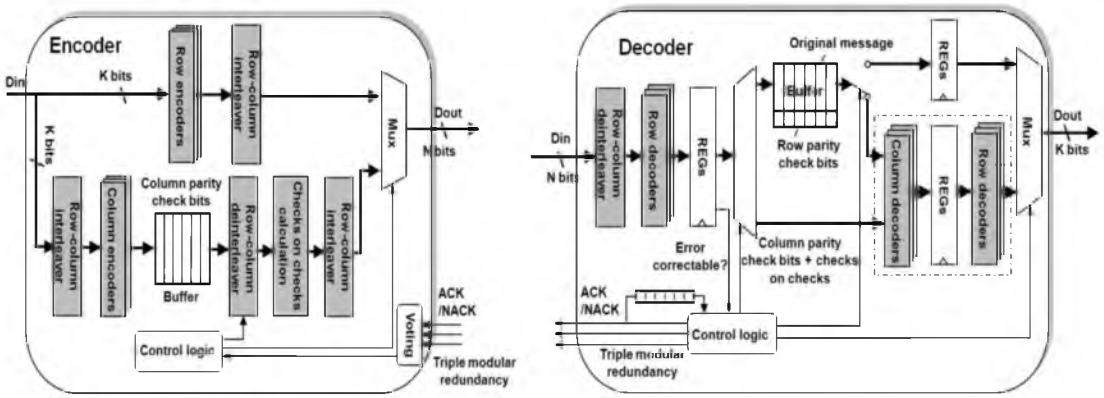

Figure 1. Encoder and decoder by Bo Fu [4]

Conclusion

The Hamming product codes are based on the Hamming code and uses the idea of cross-checking to improve the existing algorithm, which theoretically has a superior performance and effect than the existing algorithm. On-chip interconnect error correction mechanisms using such algorithms can effectively reduce link power consumption and improve stability. This algorithm is also effective in improving compiler efficiency when applied to flash compilers.

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