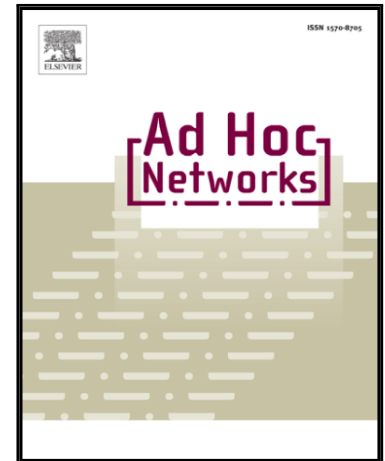


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On Short-Length Error-Correcting codes for 5G-NR

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Abstract

We compare the performance of a selection of short-length and very short-length linear binary error-correcting codes on the binary-input Gaussian noise channel, and on the fast and quasi-static flat Rayleigh fading channel. We use the probabilistic Ordered Statistics Decoder, that is universal to any code construction. As such we compare codes and not decoders. The word error rate versus the signal-to-noise ratio is found for LDPC, Reed-Muller, Polar, Turbo, Golay, random, and BCH codes at length 20, 32 and 256 bits. BCH and random codes outperform other codes in absence of a cyclic redundancy check concatenation. Under joint decoding, the concatenation of a cyclic redundancy check makes all codes perform very close to optimal lower bounds. Optimizations of the Ordered Statistics Decoder are discussed and revealed to bring near-ML performance with a notable complexity reduction, making the decoding complexity at very short length affordable.

Keywords: 5G, Error-correcting codes, Soft-Decision decoding, Complexity

1. Introduction

Information Theory [1] predicts the existence of good error-correcting codes that are capable of achieving channel capacity [2]. In the past half century coding theorists built many families of error-correcting codes [3],[4], to achieve the asymptotic fundamental limits predicted by Shannon.

Paradoxically, even in the finite block-length regime considered for practical communication systems, the channel codes used to be evaluated with respect to the channel capacity, until the work of Polyanskiy, Poor and Verdú [5] characterized with tight bounds how the non asymptotic lengths impose a severe penalty on the maximum achievable rate. Moreover, Shannon capacity is a poor benchmark in the context of the coming fifth generation of mobile networks (5G), where a plethora of services such as internet of things and augmented reality are constrained to support real-time transmissions for short packets within few milliseconds. Accordingly, the design and analysis of error-correcting codes in the short block-length regime ignited a spark of interest in the coding theory community in both academia and industry.

Our paper is dedicated to error-correcting codes of short length (typically 256 bits) and very short length (less than 32 bits). We compare the performance of the codes under equal-complexity identical decoding conditions based

on a universal decoder. We consider the binary input additive white Gaussian noise (BI-AWGN) channel, and fast and quasi-static flat Rayleigh fading channels. Over the years, many different decoding strategies have been developed [4],[6]. These strategies are often specific to one family of error-correcting codes, or are sub-optimal, favoring decoding speed over performance. For our comparison, we use the Ordered Statistics Decoder (OSD) which is a universal decoder that can decode any linear binary block code and is also near-optimal. As a result we compare codes and not decoders. The authors of [7] also compared the performance of different short-length codes (128 bits) on the BI-AWGN channel, but did not use the same decoding strategy for all codes. Some codes were decoded using a near-optimal decoder, whereas for other codes a sub-optimal decoder was used. As a result it is not always clear if one error-correcting scheme performs better than the other because of the choice of its error correcting code, or because of its decoder.

Complexity is not the main issue of this paper, but is treated for very short-length error-correcting codes for the 5G use-case where the OSD is revealed to be a viable option for practical applications.

The paper is structured as follows. System model and notations are described in Section 2. Section 3 explains OSD decoding. The discussion on the performance of short-length error-correcting codes is provided in Section 4. Very short-length codes are treated in Section 5. We conclude in the final section.

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