Strengths and limitations of machine learning techniques for polar codes

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Forward Error Correction (FEC) codes play a crucial role in digital communication systems by enabling the reliable transmission of data over noisy channels. By adding redundant information to the original data, the errors occurring during transmission can be detected and even corrected at the receiver. The scientific context of this thesis is the ANR AI4CODE research project which aims to evaluate how machine learning methods can enhance the design and decoding of error-correcting codes, whether through reducing parameters, creating more robust code structures, reducing decoding complexity, or improving error-correction performance.

Polar codes are one of the coding schemes with moderate decoding computational complexity, which makes them appealing for a wide array of applications. Introduced by Arikan in 2009, they are the first family of error-correcting codes proven to achieve the capacity of binary-input memoryless channels under Successive Cancellation (SC) decoding. It is crucial to note, however, that achieving such high-performance typically demands infinite-length polar codes. Other decoding algorithms have been introduced, mainly divided into two classes: the SC-based decoders, and the BP-based decoders. These decoders aim to improve decoding efficiency, particularly for scenarios where the theoretical benefits of polar codes are challenged by the constraints of code length and where the traditional polar construction techniques are to be replaced. The first construction techniques exploited the subchannel polarization phenomenon to rank bit channels by reliability. However, the reliance on reliability-based polar code construction did not guarantee optimal error-correction performance for all decoding algorithms.

The objective of this thesis is to leverage machine learning techniques to complement and enhance the state-of-the-art algorithms to address challenges associated with short polar code design and decoding.