# Exam question 5

1. Explain concatenated codes, Turbo codes and LDPC. Include information like coding principle and discuss performance

Shortly about coding:

Coding allows errors introduced by transmission of wireless signal to be detected and maybe even corrected. Some codes can go very close to theoretical Shannon limit with a reasonable level of complexity. The amount of error reduction of a specific code is typically given by its coding gain in AWGN and its diversity gain in a fading environmentA close up of a piece of paper

Description automatically generatedA close up of a map

Description automatically generated

Shannon channel capacity and coding gain in AWGN channels (second picture)

**Concatenated codes**

Concatenated code uses two levels of coding – inner and outer code to obtain desired performance.

Having two steps, reduces the complexity required to obtain desired error rate.

The outer code is a higher rate code which reduces the probability of error to a specified level, working at low probability of error. Concatenated codes are effective against a mixture of random errors and bursts.

Outer code is typically Reed Solomon code.

Inner decoder uses all the available soft decision data to provide the best performance under Gaussian conditions. For a one-level concatenated code, if the minimum distances of the inner and outer codes are d1 and d2 then the minimum distance of the concatenation is at least d1d2.

Choice of the inner code is dictated by the application –

* For high data rates, inner code should be a block code
* For predominantly slower Gaussian channels the inner code should be a convolution code.

Concatenated codes typically achieve performance with less complexity than one single code. However, the technique is sub-optimal since encoding/decoding is done in two isolated stages, whereas in reality the two are working together to solve the same issue

**Turbo codes**

In principle turbo code adds an iterative loop functionality to the concept of concatenated codes. Turbo codes can achieve large coding gains by combining two or more relatively simple building blocks. Turbo codes make it possible to increase available bandwidth without increasing the power of a transmission, or they can be used to decrease the amount of power used to transmit at a certain data rate. Main drawbacks are the relative high decoding complexity and a relatively high latency, which makes it unsuitable for some applications.

RSC – Recursive Systematic Convolutional Coder – is constructed from a standard convolutional encoder by feeding back one of the outputs. An RSC code is systematic – the input bits appear directly in the output. An RSC encoder is an Infinite Impulse Response filter – an arbitrary input will cause a good output with high probability and some inputs will cause bad outputs.

Strong turbo code is created by encoding in parallel. A non-uniform interleaver scrambles the ordering of bits at the input of the second order. It is very unlikely that both encoders produce low weight code words.

Random coding interpretation of turbo codes.

Random codes achieve the best performance however, random codes are not feasible – the code must contain enough structure so that decoding can be realized with actual hardware.

**Application of Turbo codes**: Third generation cellular – UMTS/3GPP …

**LDPC codes**

Low-Density Parity-Check

Very good coding gain performance. Can achieve Turbo Code like performance but the implementation cost is much lower - therefore they have also become extremely popular.

Low density comes from the generator matrix with few 1’s

Encoding is a matrix operation. However large and sparse LDPC matrix poses implementation problem. Decoding problem is to find the most probable vector x such that Hx mod 2 = 0. To achieve good coding gain performance good LDPC code design is essential.

Application for LDPC – Wireless, Optical … communications, WiMax

Coding performance factors – Latency vs performance, Complexity vs performance, Spectral efficiency vs performance

Turbo – extraordinary performance at low SNR

LDPC – can achieve turbo code like performance and implementation cost is lower