

Poli-Nokia

Innovative teaching

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Nokia Vimercate
April 18, 2023

The Nokia logo is centered within a large white circle that occupies the right half of the slide. The background of the slide is a green-to-blue gradient.

NOKIA



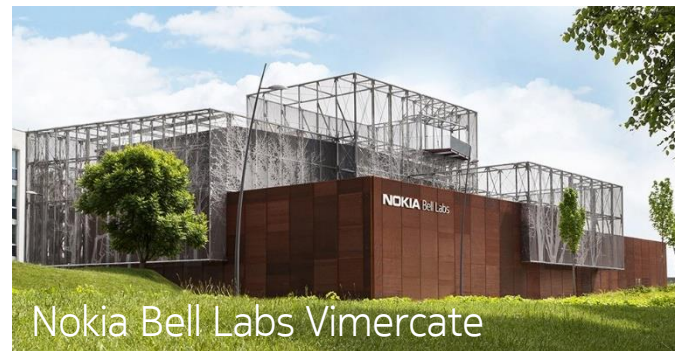
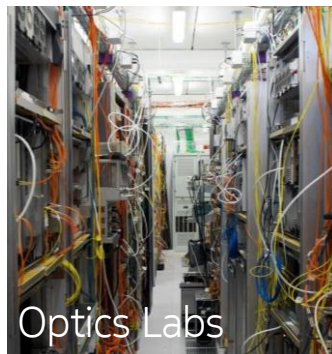
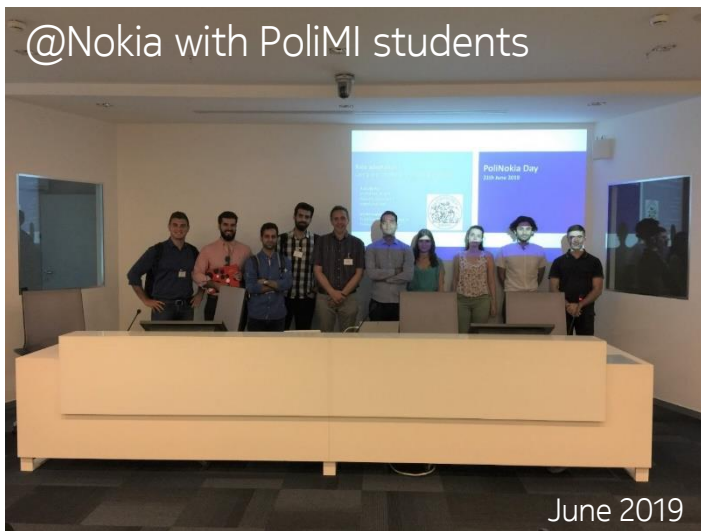
POLITECNICO
MILANO 1863

NOKIA

5th Poli-Nokia Communication Symposium
Nokia Vimercate, 2023

Communication Symposium

@Nokia with PoliMI students



NOKIA Bell Labs

Inventing the Future X Network

Creation of Bell Labs

The engineering departments of the American Telephone and Telegraph Company (AT&T) and Western Electric were consolidated into Bell Telephone Laboratories. Their mission was to research and design communication technologies for the rapidly expanding telephone network and to explore fundamental areas of science that could shape the future of the industry. Over the years, many cornerstone technologies of modern society have been invented at Bell Labs and 6 Nobel Prizes have been awarded to its researchers.



1954
Solar cells

1925



1940's

1956
Transistor

To replace the vacuum tube, Bardeen, Brattain and Shockley created a working point-contact transistor. This basic building block for all digital products is the foundation for our information society.

1948
"A Mathematical Theory of Communications"

By showing that all communications channels - of any type - have a fundamental capacity limit, Claude E. Shannon founded the field of information theory.



1937
Electron Diffraction

Demonstrating wave nature of matter

1970's

1973
UNIX and C Language

Thompson and Ritchie's elegant design made it an immediate hit with the programming community when it was released in 1974. UNIX would later on become the Internet's foundation.



1995
Integrated ADSL Chip

After co-inventing ADSL technology, follow-up innovations like vectoring continued to generate world records for high speed data transfer over copper telephone lines, fueling the Internet.

1980's

1980
Demonstration of DSP

Large-scale integrated circuit for digital signal processing



1998
Wireless MIMO Spatial Multiplexing

Invention of wireless transmission based on multiple spatial paths

1998
Fractional Quantum Hall Effect

Discovery of a novel collective quantum fluid state of matter



1997
Laser-Based Cooling and Trapping of Atoms

To understand the fundamental limits of materials and matter

1995
Commercial DWDM

Pioneering work on wavelength multiplexing in optical fibers



1978
Commercial Cellular Network

Invention of the cellular concept and creation of the first commercial network



1978
Cosmic Microwave Background Radiation

Pioneering work on radio communications using the Holmdel Horn Antenna provides support for the Big Bang Theory



1977
Electronic Structure of Magnets and Glasses

1976
Fiber Optic Network

First demonstration of 45 Mbit/s transmission



2006
Software Defined Routing

Precursor of Software Defined Networks (SDN)

2009
CCD

Boyle and Smith's picture phone research realized the enormous potential of the Charge Coupled Device as an imaging device, leading to the invention of the digital photo, video cameras, scanners, satellite surveillance and ultra-sensitive astronomical telescopes



2009
Coherent 100G Optics

Invention of the future of high speed optical communications with coherent processing



2009
World's first standard compliant LTE call



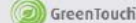
2014
Fluorescence Microscopy

Ground-breaking work on sub-wavelength optical microscopy leads to super-resolution microscopy at cellular level



2015
GreenTouch

International consortium delivers new technologies to improve energy efficiency in wireless networks by more than 10,000X



2015
Optical MIMO-SDM

Pioneering work on utilizing the spatial dimension in fiber, showing greater than 10X increase in optical network capacity

2015
The Future X Network: A Nokia Bell Labs Perspective

First Nokia Bell Labs book written



2016
5G Massive Connectivity

First demonstration of 1M simultaneous, ultra-low latency connections in a single cell for 5G and IoT

2020's

The Future

Nokia Bell Labs continues to solve the great industry challenges, producing disruptive innovations for the next phase of human existence

Your research?

Nokia in Italy

An all-functions
hub serving the
worldwide market

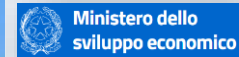
Sites

- Vimercate
(Headquarters, 1000+ people)
- Rome
- Trieste
- Battipaglia

R&D Domains

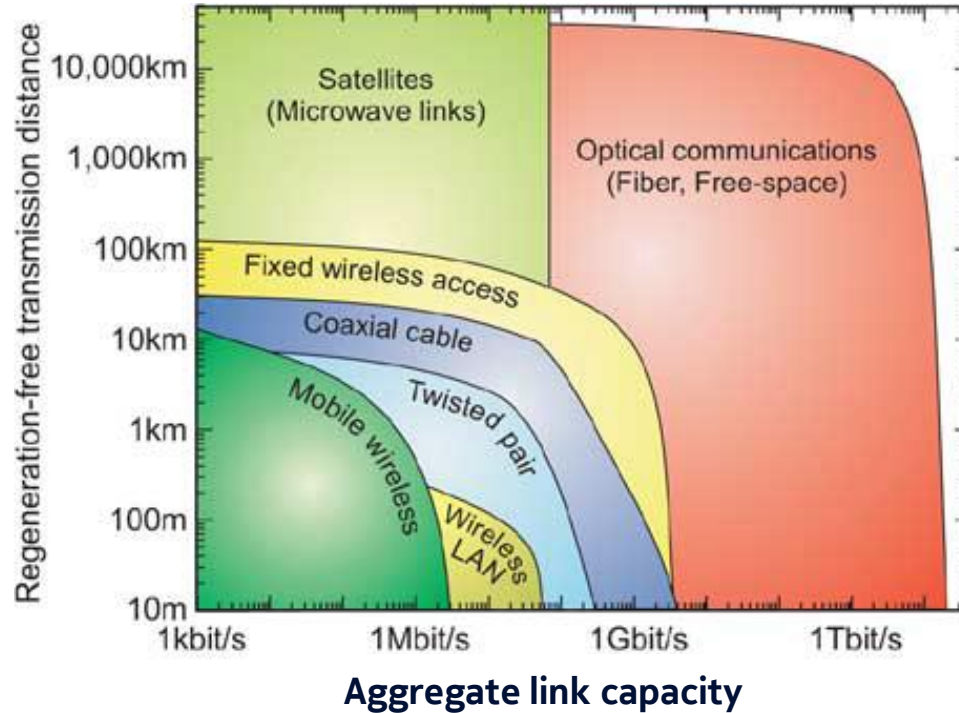
- Product Development
Optical technology products
Microwave products
- Bell Labs Research
- Analytics
ML and AI technology
- 5G Augmented/virtual
Reality

Partnerships



Why Optical Communications?

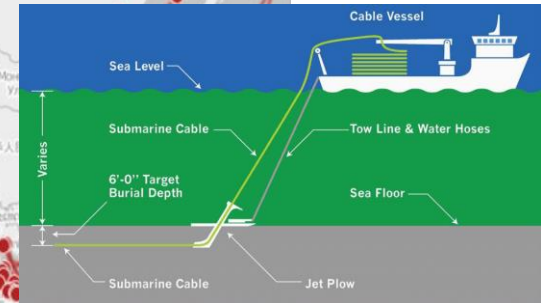
Proc. IEEE 94, 952-985 (2006)



Commercial C-band WDM systems

- 19 Tb/s long-haul networks
- 35 Tb/s metro networks
- 88 Channels (50GHz) by wavelength multiplexing

Submarine Networks



- **500+ subsea cables**
- **1.4 million kilometers of total length**
(more than 3x distance Earth-Moon)

[ASN - Who we are](#)
[Submarine Cable Map](#)
[Submarine Cable Map 2023 \(telegeography.com\)](#)
[Submarine Cable FAQs \(telegeography.com\)](#)

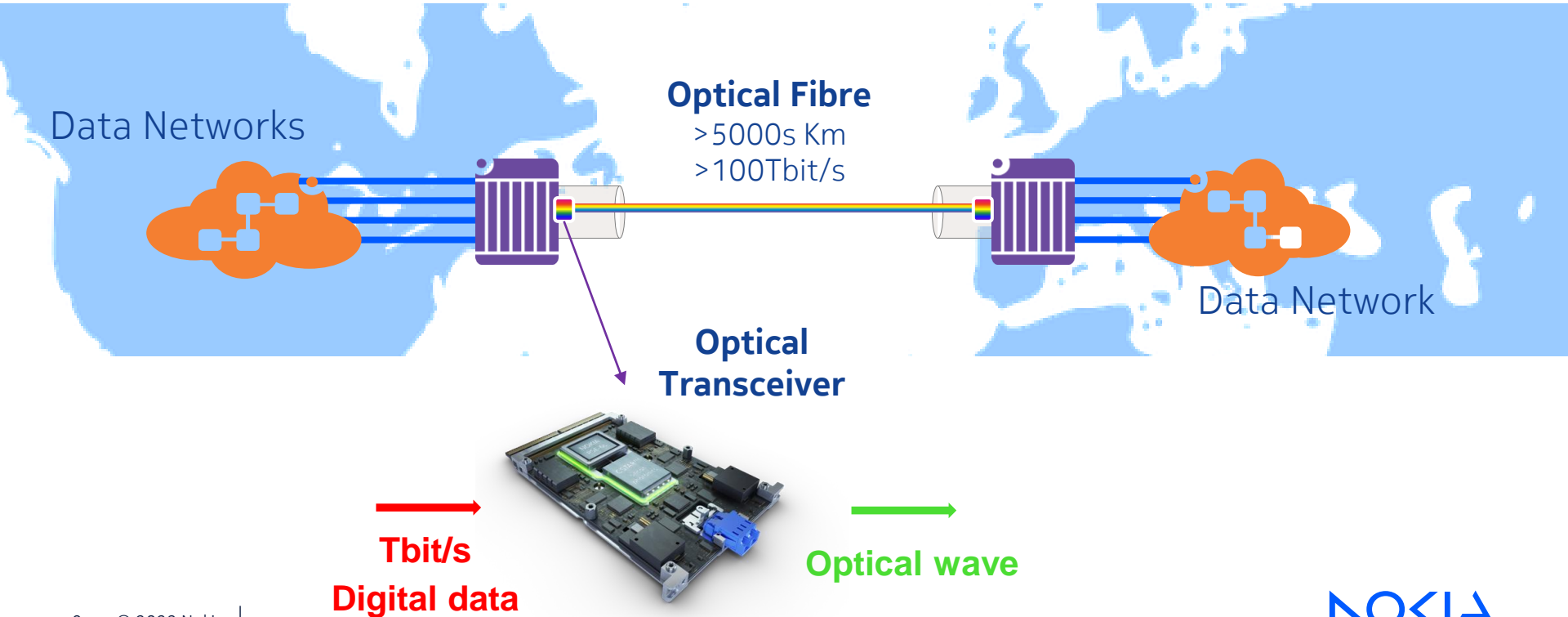
The Arctic Fiber Project



- Europe-Japan connection
- ~15.000 Km link
- Low latency transmission

Nokia Optical R&D in Vimercate

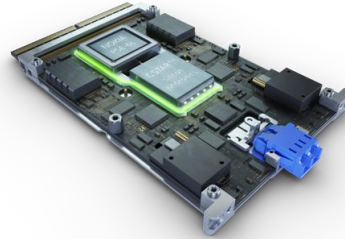
Transceiver design



Nokia Optical R&D in Vimercate

Transceiver design

→
1.2 Tbit/s
Digital data



→
Optical wave



6th generation super-coherent technology

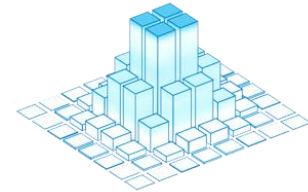
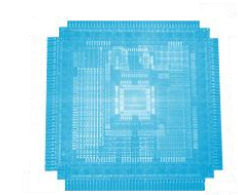
Latest C-MOS ASIC

Highly integrated DSP and Optics

Shaped-QAM modulation

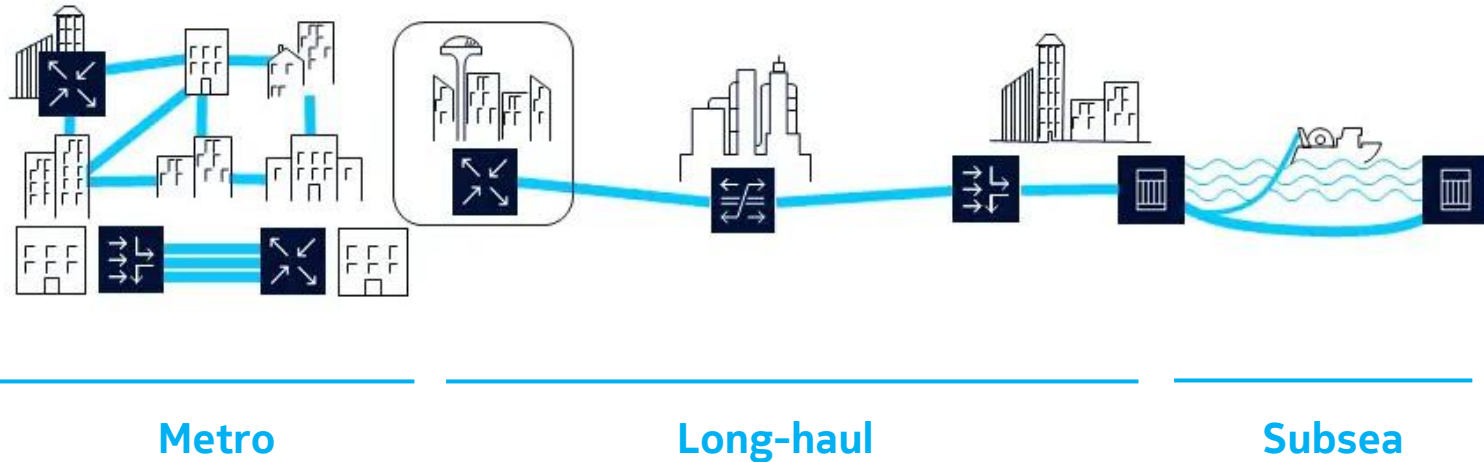
Advanced DSP fibre equalisation

High performance Forward Error Correction

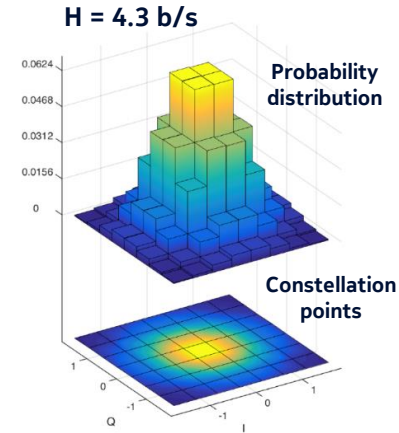
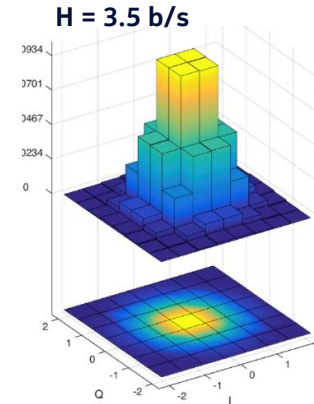
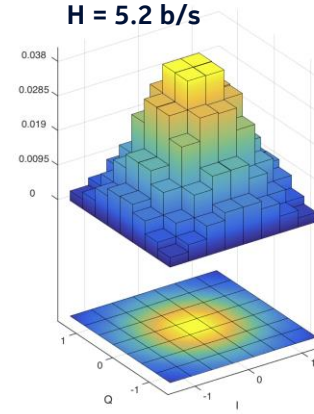
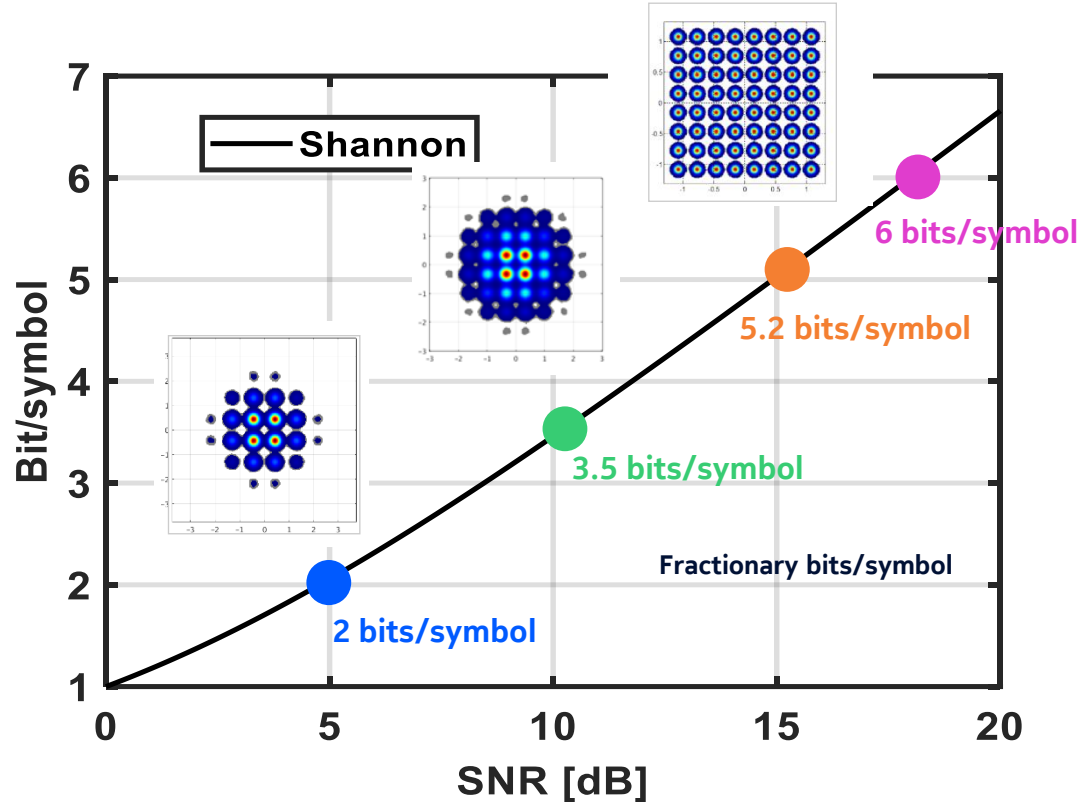


What is our challenge?

Design of transceivers to maximise capacity in a variety of optical links

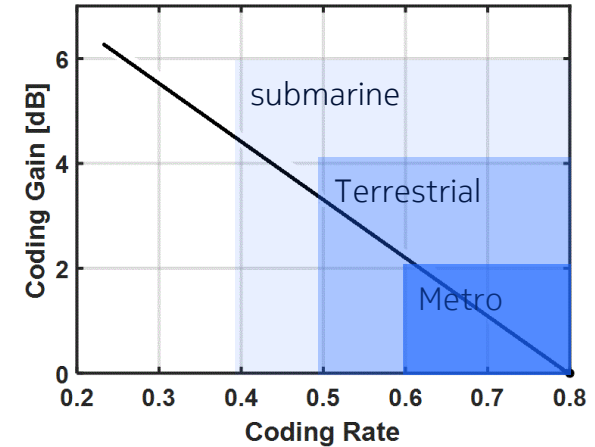
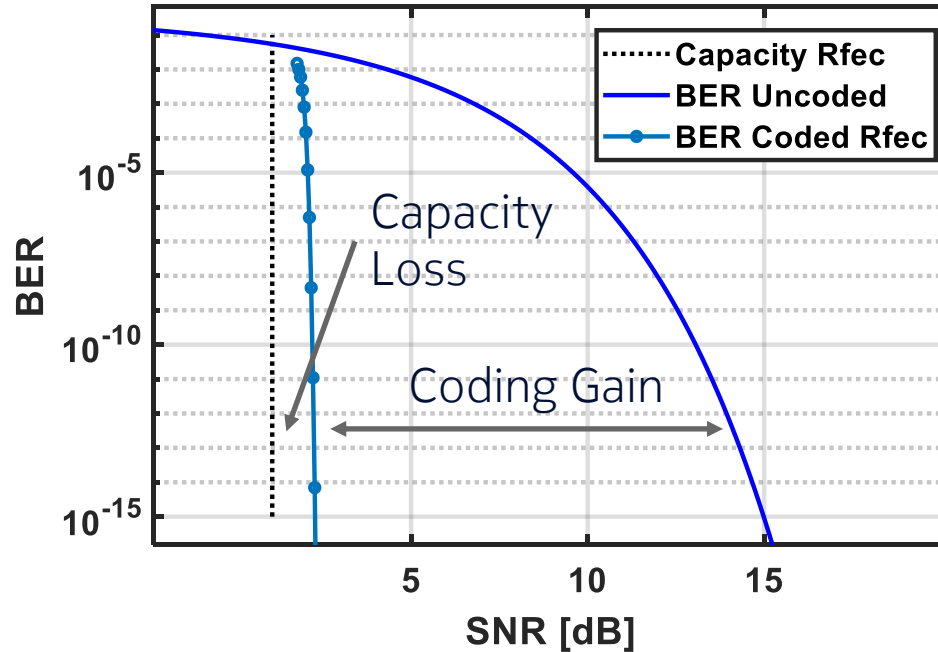


Modulation for Optics: Probabilistically shaped QAM



Iterative Soft Forward Error Correction

Variable FEC Rates



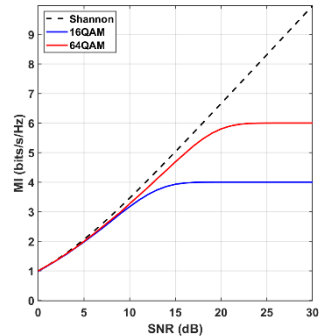
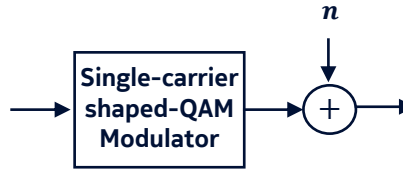
Projects

1. Multi-carrier modulation over the optical channel
2. Variable rate LDPC code for subsea transmission
3. Machine learning for soft FEC decoding

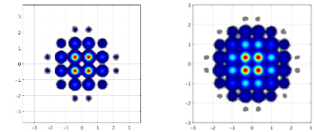
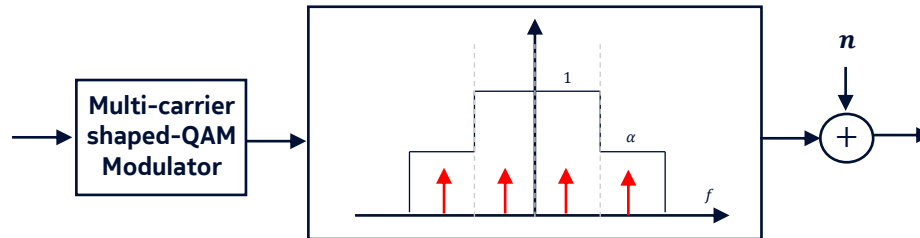
Project 1: Multi-carrier modulation over the optical channel

In optical **multi-carrier transmission systems** information is modulated using **probabilistic shaping** on multiple adjacent carriers which are transmitted over the same fibre link.

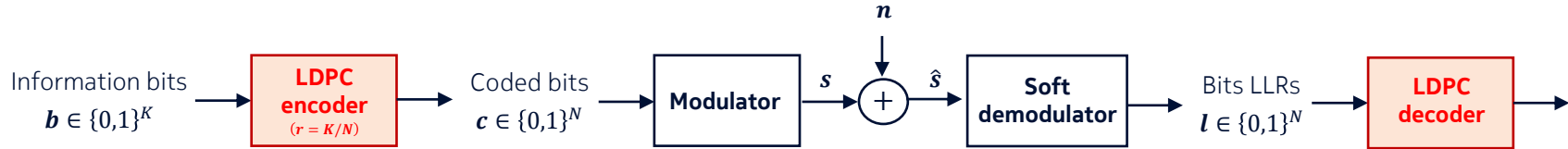
1) What is the constrained capacity of a **single-carrier shaped-16/64 QAM**?



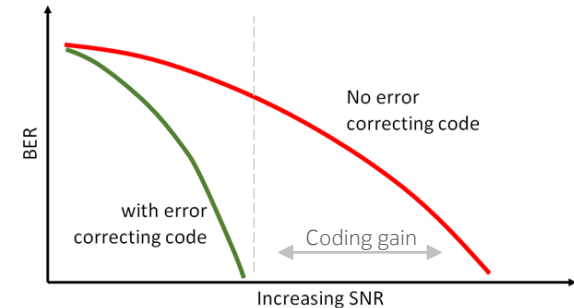
2) What is the achievable capacity of a **4-carrier shaped 16/64QAM** over a filtered channel?



Project 2: Variable rate LDPC code for subsea transmission



- In **low density parity check codes (LDPC)**, parity check matrix \mathbf{H} contains mostly 0's and relatively few 1's.
- LDPC codes **closely approach Shannon capacity**, with high computational efficiency.
- The use of LDPC codes is **extremely important in coherent optical subsea systems due to the prohibitive distances** to be covered (thousands of kilometers).



Project 2: Objectives

Variable rate LDPC code for subsea transmission

Consider a QAM modulation format and an AWGN channel:

- 1) Build a MATLAB code to simulate the performance of an AWGN system with **LDPC coding scheme**.
- 2) Study **system performance and coding gain** as a function of LDPC **variable code rates**.
- 3) Assuming that the optical channel is AWGN, how much the **system reach** can be increased?

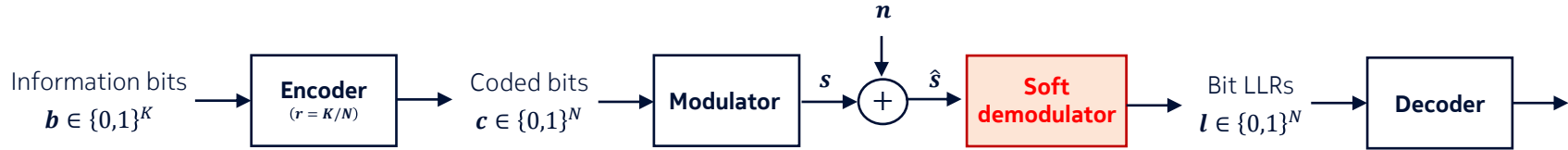
[1] [Low-density parity-check \(LDPC\) codes from DVB-S.2 standard - MATLAB dvbs2ldpc - MathWorks Italia](#)

[2] [Create LDPC encoder configuration - MATLAB - MathWorks Italia](#)

[3] [Encode binary LDPC code - MATLAB ldpcEncode - MathWorks Italia](#)

[4] [Decode binary LDPC code - MATLAB ldpcDecode - MathWorks Italia](#)

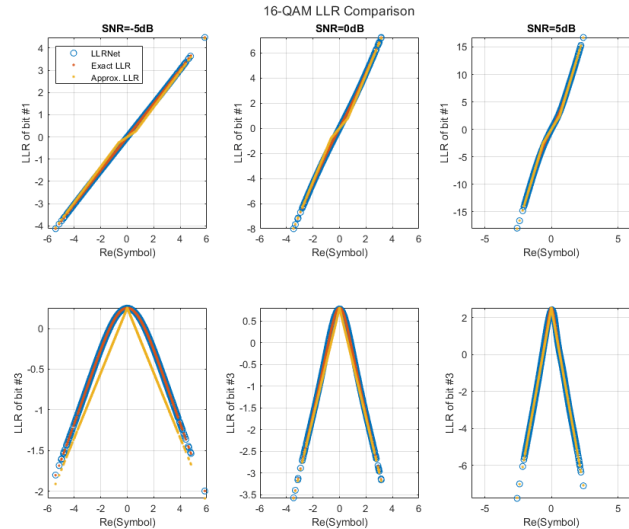
Project 3: Machine learning for soft FEC decoding



- **Log likelihood ratio (LLR)** via *log-MAP*.

$$l_i = LLR(c_i) = \log \left(\frac{P(c_i = 0 | \hat{s})}{P(c_i = 1 | \hat{s})} \right)$$

- Soft bits (bit LLRs) feed a following stage of error correction (FEC) decoding, a **crucial component in any communication system**.
- **LLRs evaluation is computationally expensive**, especially for large constellations!

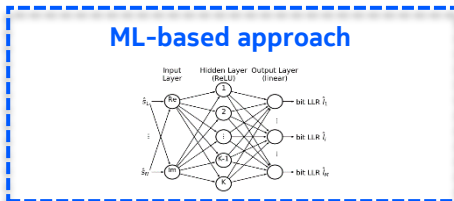


Project 3: Objectives

Machine learning for soft FEC decoding

Consider a QAM modulation format and an AWGN channel:

- 1) Evaluate **bit LLRs** analytically and by means of max-log approximation.
- 2) Build a MATLAB code to **estimate bit LLRs**, either by using a «machine learning-based approach» or by an «information theoretic approach».
- 3) Simulate the performance of a system which uses a soft demodulator to generate inputs for a LDPC decoder.



Information theoretic approach

$$l_i = LLR(c_i) = \log \left(\frac{P(c_i = 0|\hat{s})}{P(c_i = 1|\hat{s})} \right)$$

[1] <https://it.mathworks.com/help/comm/ug/training-and-testing-a-neural-network-for-llr-estimation.html>

[2] <http://www.dsplog.com/2009/07/05/softbit-16qam/>

[3] O. Shental et al. "Machine LLRning: Learning to Softly Demodulate"

Projects

Summary

Project 1: Multi-carrier modulation over the optical channel

[1] F. Buchali, J. Lightwave Technology, V.34, N.7, 2016, pp. 1599

[2] <https://www.nokia.com/blog/nokia-innovation-in-single-carrier-and-multi-carrier-coherent-optics/>

Project 2: Variable rate LDPC code for subsea transmission

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Master Thesis with Nokia

1) Topics for your thesis will be on technologies for **Optical Transmission:**

1. High-capacity optical transmitter and receiver architectures
2. Advanced modulation formats and demodulation techniques
3. Adaptive equalisation and algorithms for the optical channel
4. Capacity achieving Forward Error Correction codes

2) Master students will work in Nokia laboratories with our research team for the duration of their thesis and receive an **intern salary + lunch tickets**, an office desk, a laptop and access to software tools.

3) Best students are usually offered a permanent position in Nokia R&D.



If you want to innovate in the information technology industry....
Get in touch with prof. Magarini and prof. Barletta!

Contacts

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