Poli-Nokia

Innovative teaching

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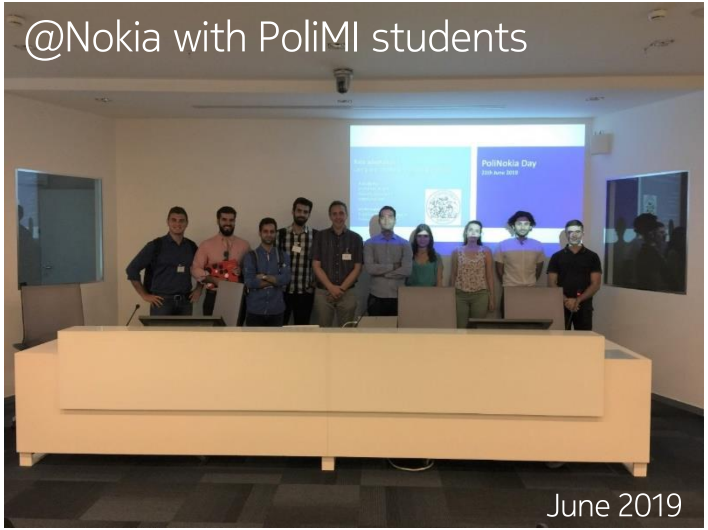
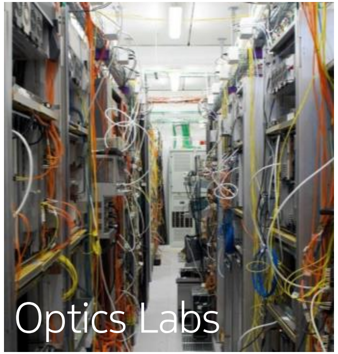
Nokia Vimercate
April 18, 2023

5th Poli-Nokia Communication Symposium

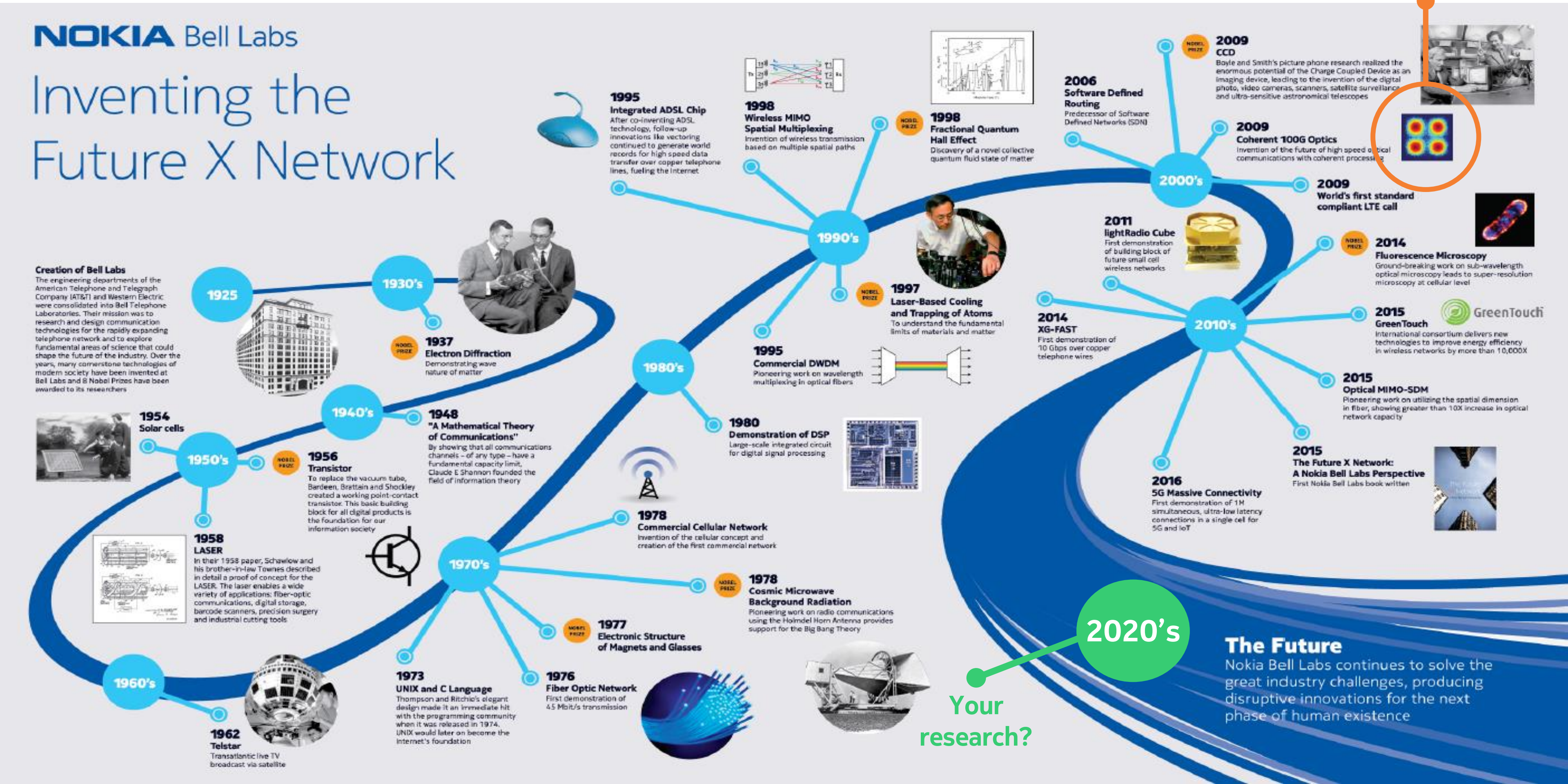
Nokia Vimercate, 2023

Communication Symposium





Coherent Optics
2009



Nokia in Italy

An **all-functions hub** serving the worldwide market

Sites

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

R&D Domains

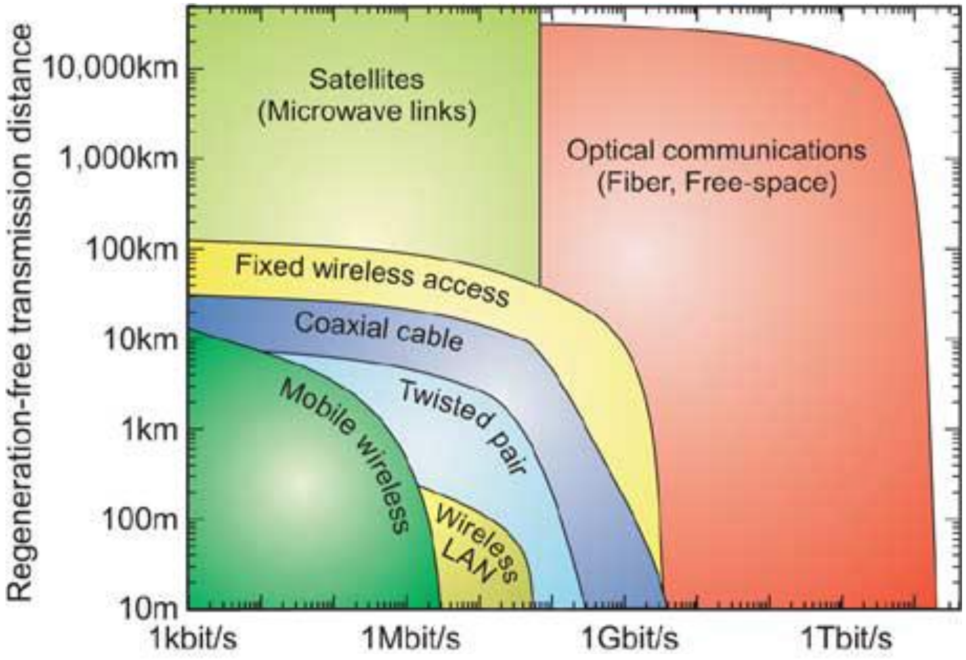
- Product Development
  Optical technology products
  Microwave products
- Bell Labs Research
- Analytics
  ML and AI technology
- 5G Augmented/virtual Reality

Partnerships

bts
POLITECNICO MILANO 1863
Cefriel POLITECNICO DI MILANO
ASSOLOMBARDA Confindustria Milano Monza e Brianza
CLUSTER SCC LOMBARDIA
Ministero dello sviluppo economico
Regione Lombardia

Why Optical Communications?

Proc. IEEE 94, 952-985 (2006)

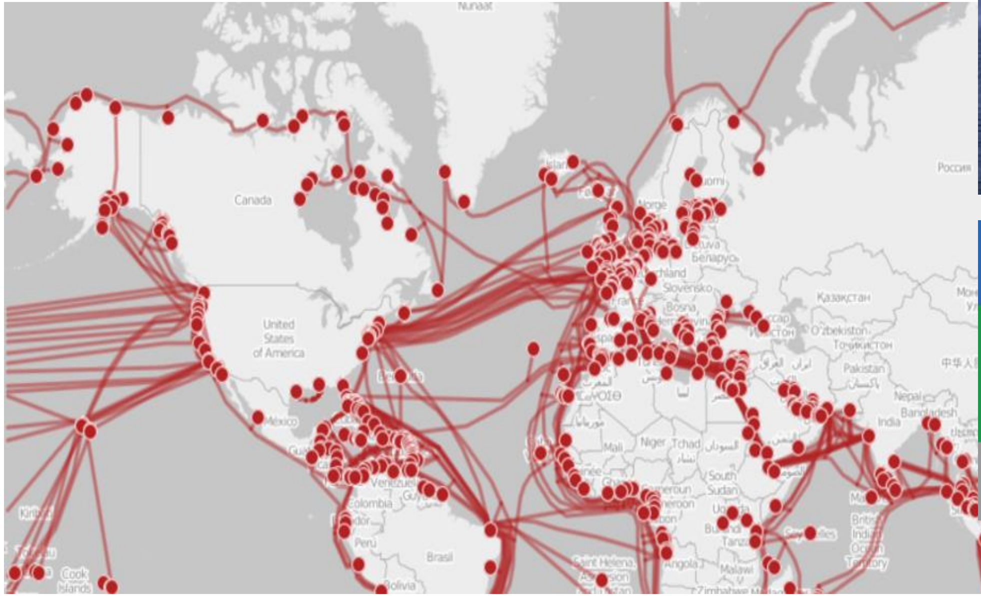


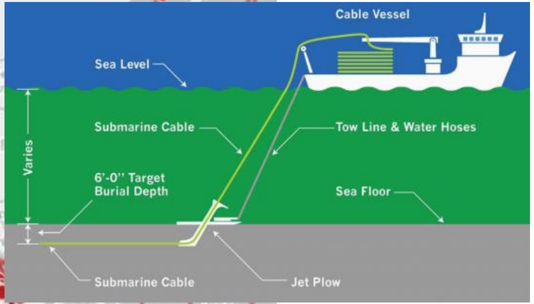
Aggregate link capacity

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)

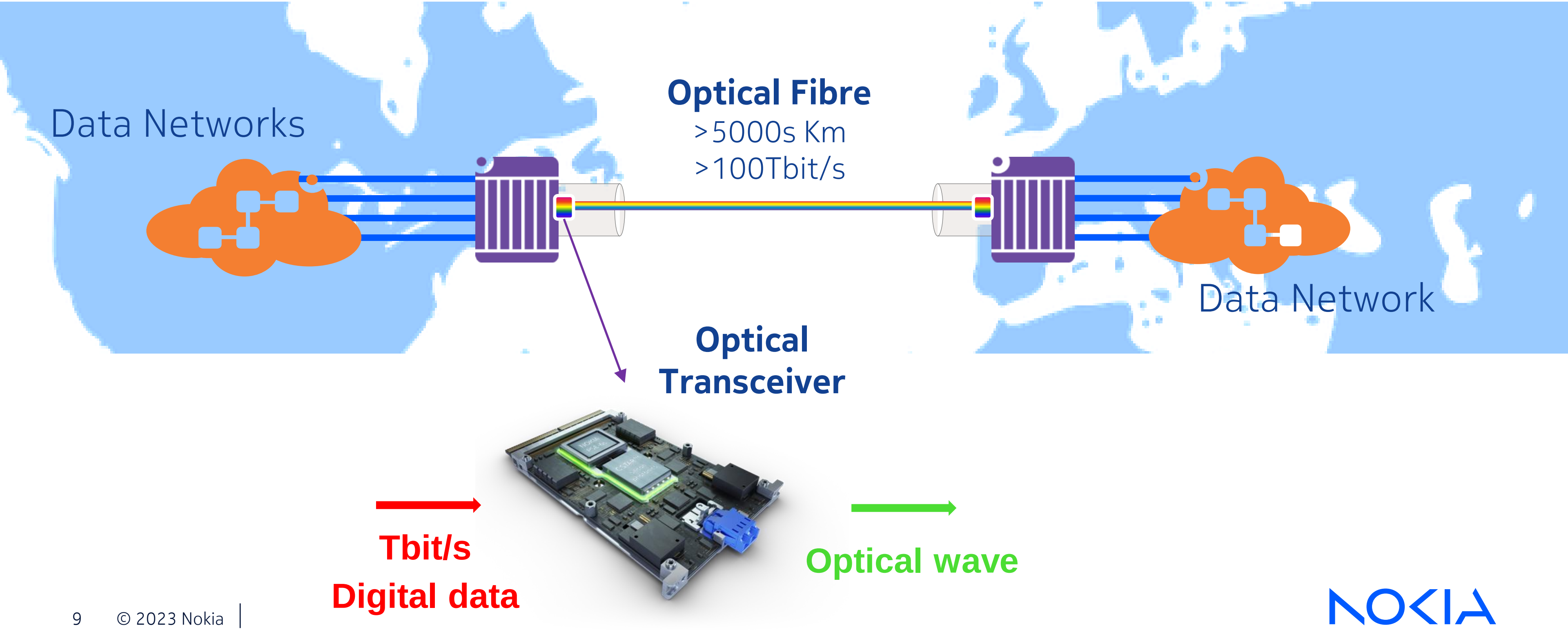
[ASN - Who we are](#)
[Submarine Cable Map](#)
[Submarine Cable Map 2023 (telegeography.com)](#)
[Submarine Cable FAQs (telegeography.com)](#)

The Arctic Fiber Project

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

Nokia Optical R&D in Vimercate

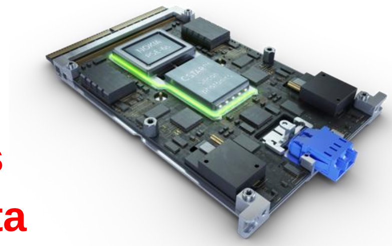
Transceiver design



Nokia Optical R&D in Vimercate

Transceiver design

1.2 Tbit/s
Digital data



Optical wave

6th generation super-coherent technology

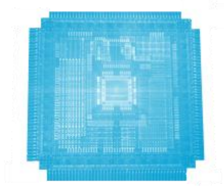
Latest C-MOS ASIC

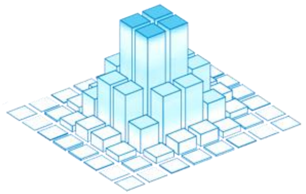
Highly integrated DSP and Optics

Shaped-QAM modulation

Advanced DSP fibre equalisation

High performance Forward Error Correction





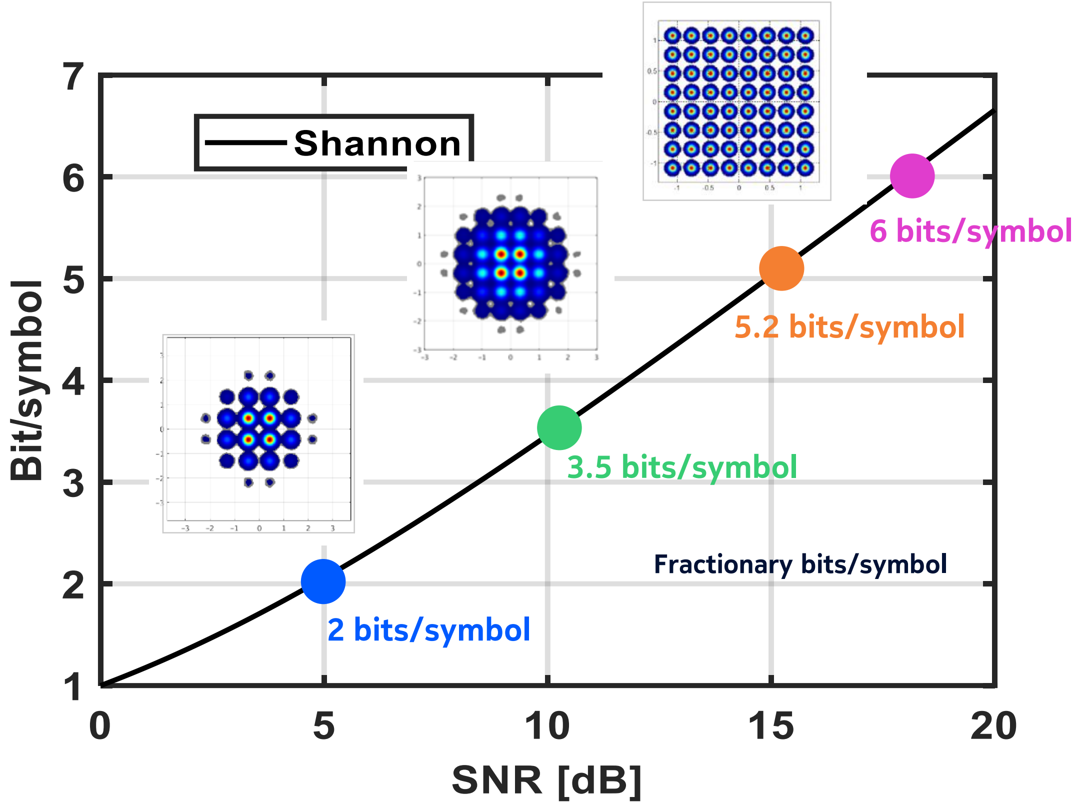
https://www.nokia.com/networks/technologies/photonic-service-engine/
https://www.youtube.com/watch?v=xGy-fujK1-c&feature=emb_imp_woyt
https://www.youtube.com/watch?v=QnLYu5EcXrM

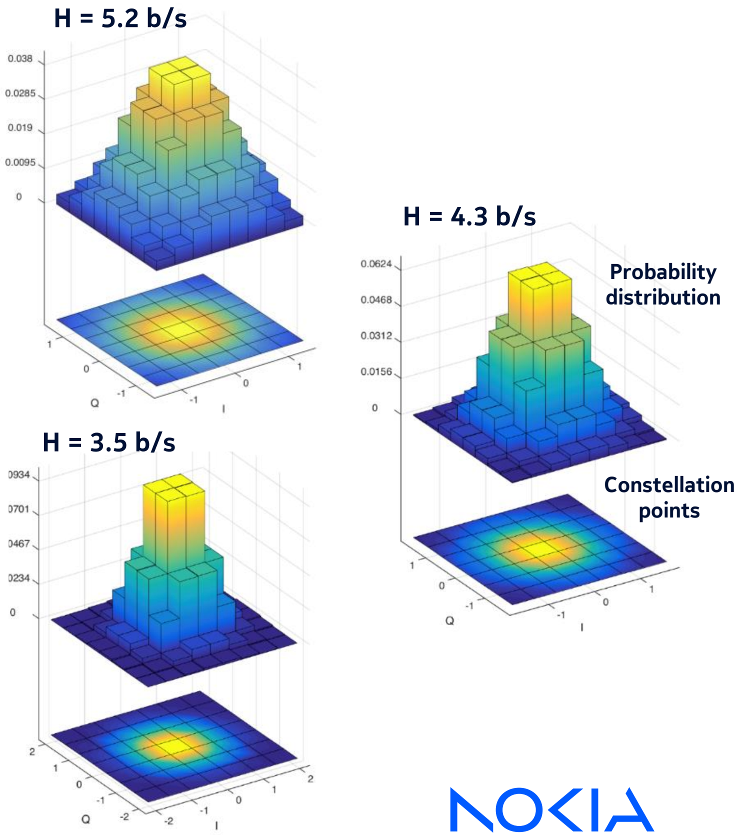
What is our challenge?

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

Metro **Long-haul** **Subsea**

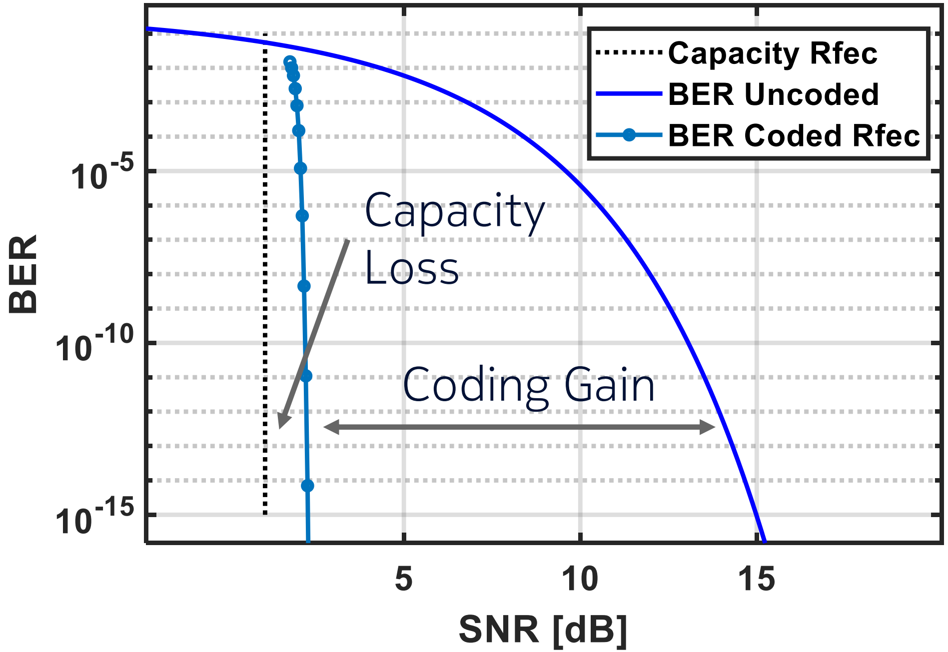
Modulation for Optics: Probabilistically shaped QAM

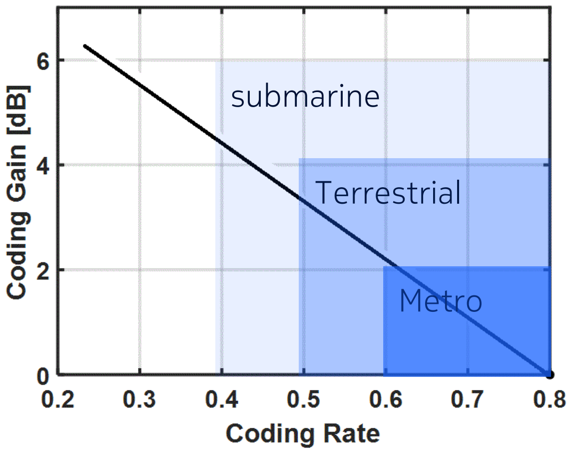




Iterative Soft Forward Error Correction

Variable FEC Rates





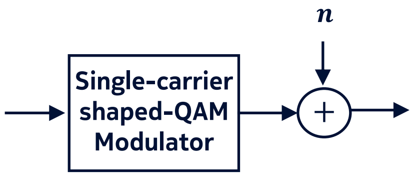
Projects

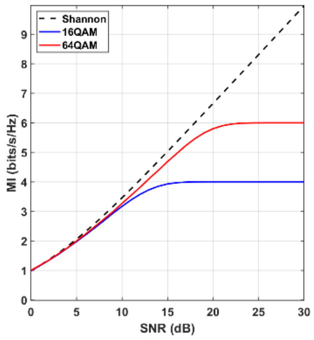
1. Multi-carrier modulation over the optical channel
2. Variable rate LDPC code for subsea transmission
3. Machine learning for soft FEC decoding

Project 1: Multi-carrier modulation over the optical channel

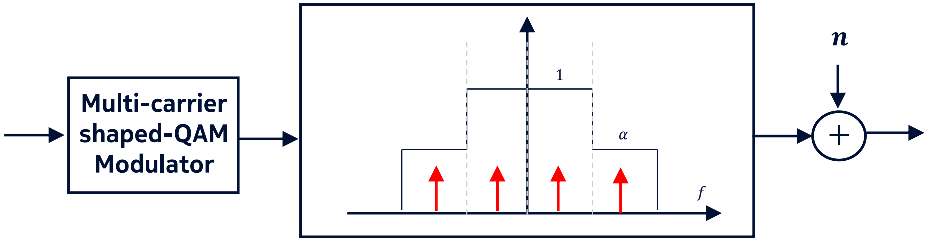
In optical **multi-carrier transmission systems** information is modulated using **probabilistic shaping** on multiple adjacent carriers which are transmitted over the same fibre link.

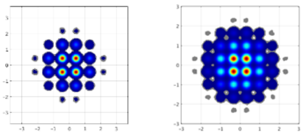
1) What is the constrained capacity of a **single-carrier shaped-16/64 QAM**?





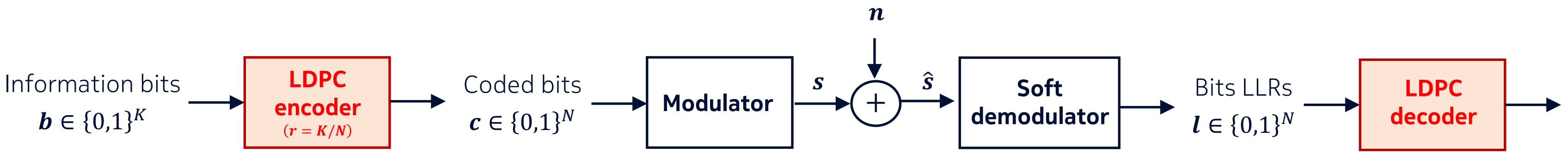
2) What is the achievable capacity of a **4-carrier shaped 16/64QAM** over a filtered channel?



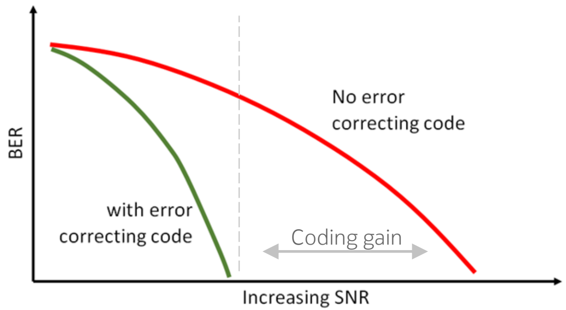


[1] F. Buchali, J. Lightwave Technology, V.34, N.7, 2016, pp. 1599
[2] https://www.nokia.com/blog/nokia-innovation-in-single-carrier-and-multi-carrier-coherent-optics/

Project 2: Variable rate LDPC code for subsea transmission



- In **low density parity check codes (LDPC)**, parity check matrix 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
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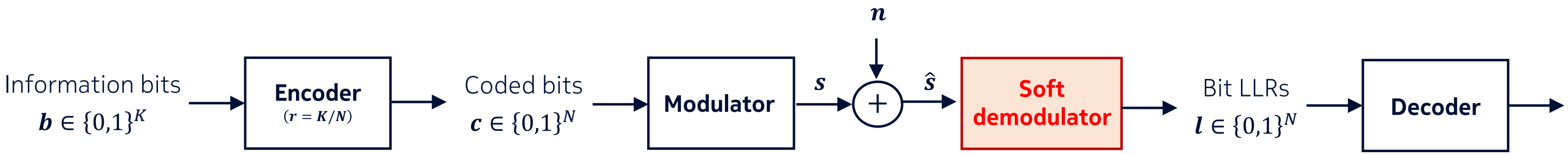
Project 3: Machine learning for soft FEC decoding

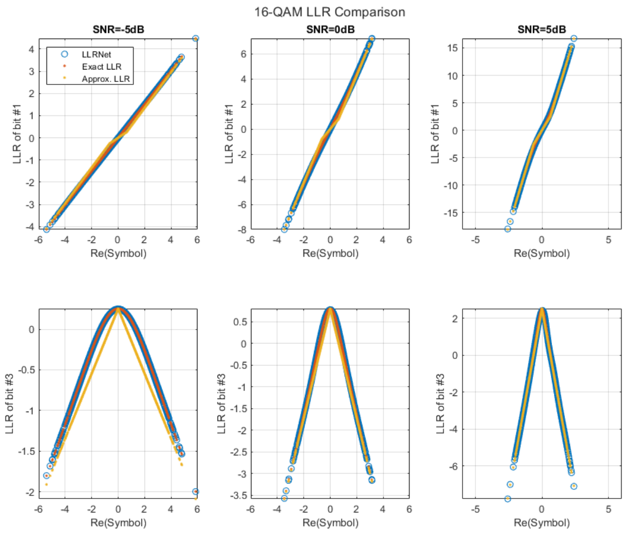


- **Log likelihood ratio (LLR)** via *log-MAP*:

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

- 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

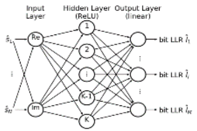
Consider a QAM modulation format and an AWGN channel:

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.

ML-based approach



Information theoretic approach

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

[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

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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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Giancarlo Gavioli: giancarlo.gavioli@nokia.com

NOKIA