

# Course guide 230261 - SON - Smart Optical Networks

Last modified: 24/05/2024

Academic year: 2024	ECTS Credits: 6.0 Languages: Catalan, Spanish, English		
	2015). (Optional subject). BACHELOR'S DEGREE IN DATA SCIENCE AND ENGINEERING (Syllabus 2017). (Optional subject).		
Degree:	BACHELOR'S DEGREE IN TELECOMMUNICATIONS TECHNOLOGIES AND SERVICES ENGINEERING (Syllabus		
Teaching unit:	739 - TSC - Department of Signal Theory and Communications.		
Unit in charge:	Barcelona School of Telecommunications Engineering		

LECTURER	
Coordinating lecturer:	JOSE ANTONIO LAZARO VILLA
Others:	Primer quadrimestre: JOSE ANTONIO LAZARO VILLA - 11

### **PRIOR SKILLS**

Basic backgrond on communications

### **TEACHING METHODOLOGY**

In the fall classes taught in English, and Spanish and Catalan in the spring (if it is the case and programmed).

- Lectures.
- Group work.
- Individual work.
- Laboratory Practices.
- Exercises.
- Oral presentations.
- Short answer test.
- Extended answer test.

### LEARNING OBJECTIVES OF THE SUBJECT

TThe techniques of Artificial Intelligence, Machine Learning, Deep Learning, Reinforcement Learning, etc. they are helping to develop communications in general and optical networks in particular more flexible, more capable, and more autonomous. This course provides an overview, at the undergraduate level, of optical networks, from the beginning, as the backbone of the Internet to current networks, integrating home access, mobile network support, intercontinental and intelligence. to provide flexible and robust services. It is not an extensive course in AI, ML, DL, RL, or all the technologies used in optical communications, which have made broadband communications possible everywhere. Each of these concepts and technologies can be extended in several subjects of the MET and MATT Masters. The aim is to give a global and specific view of the synergies between various technologies, both software and hardware in the optical networks and the intelligence they are developing.

Finally, new concepts of AI, ML, DL, RL are also presented, which are being developed as a result of networks (communications, social, etc.), opening up the traditional field of application of these concepts.



### STUDY LOAD

Туре	Hours	Percentage
Hours large group	39,0	26.00
Self study	98,0	65.33
Hours small group	13,0	8.67

Total learning time: 150 h

### CONTENTS

#### 1. Introduction

#### **Description:**

- Historical evolution of the Internet infrastructure.

- Current situation.

- Basic Concepts of Artificial Intelligence and Machine Learning

Full-or-part-time: 17h 18m Theory classes: 6h Self study : 11h 18m

#### 2. Internet Core and access networks

### **Description:**

- Evolution of Internet backbones and current networks based on "Wavelength División Multiplexing" (WDM)

- Internet access technologies, from the "pre-optical" era to the current "Fiber-to-the-Home" (FTTH) and the "Passive Optical Networks" (PON)

- Introduction to the 100 Gigabit Ethernet standard and current commercial equipment

**Full-or-part-time:** 17h 18m Theory classes: 6h Self study : 11h 18m

#### 3. High capacity telecommunication systems - the optical layer

### **Description:**

- New optical fibers and their benefits.

- High capacity telecommunications systems with coherent technology and modulation of amplitude, phase (and polarization) of light.

- "Machine Learning" and "Deep Learning" techniques for new high capacity optical communication systems.

- The optical distribution network in new mobile communications. (5G, 6G)

**Full-or-part-time:** 17h 18m Theory classes: 6h

Self study : 11h 18m



#### 4. WDM telecommunication systems elements

#### **Description:**

- Optical devices for WDM communications.
- Optical amplification in WDM communication systems.

#### **Related activities:**

- LABORATORY PRACTICES: Erbi-doped fiber optic optical amplifiers.

Full-or-part-time: 26h Theory classes: 5h Laboratory classes: 4h Self study : 17h

#### 5. Optical-fiber network fundamentals

#### **Description:**

- WDM systems for long distance links.
- Optimization of optical amplifiers in long distance networks using "Machine Learning" techniques.
- Protection systems against network failure and attacks: physical and technical devices of "Machine learning".
- Wavelength conversion.

Full-or-part-time: 17h 18m Theory classes: 6h Self study : 11h 18m

#### 6. WDM network design and analysis

#### **Description:**

- Routing and assignment of wavelengths

- Resolution of optimal allocation of resources in networks using "Integer Linear Programming" (ILP) and "NP-complete" computational complexity problems.

- Heuristic algorithms for routing and assigning wavelengths
- Resolution using "Deep Reinforcement Learning" techniques and introduction to "Graph Neural Networks".

#### **Related activities:**

PRACTICES with Matlab / Python: Routing resolution and wavelength assignment, heuristic algorithms vs "Deep Learning".

## Full-or-part-time: 37h 30m Theory classes: 5h

Practical classes: 8h Self study : 24h 30m

### 7. Network control and management

#### **Description:**

- Basic functions of network control and management.
- Introduction to the ITU-T G.8080 standard (Optical switching network architecture ASON)
- "Software Defined Networking" (SDN) in optical networks and new lines of research in optical networks

#### Full-or-part-time: 17h 18m

Theory classes: 6h Self study : 11h 18m



### **GRADING SYSTEM**

The final grade for the course will be obtained from the continuous assessment grade (work proposed by the teacher throughout the course and laboratory practices) and the final exam, according to the following criteria:

Exercises: 20% Laboratory Practices: 30% Partial examinations: 25% Final examination: 25%

### **BIBLIOGRAPHY**

#### **Basic:**

- Sutton, R.S.; Barto, A.G. Reinforcement learning: an introduction [on line]. 2nd. ed. Cambridge, Mass: MIT Press, 2018 [Consultation: 05/07/2021]. Available on: <u>https://ebookcentral.proquest.com/lib/upcatalunya-ebooks/detail.action?docID=6260249</u> ISBN 9780262039246. ISBN 9780262039246.

- Ramaswami, R.; Sivarajan, K.N.; Sasaki, G.H. Optical networks: a practical perspective [on line]. 3rd. ed. San Francisco: Morgan kaufmann, 2010 [Consultation: 05/07/2021]. Available on: <u>https://www.sciencedirect.com/science/book/9780123740922</u>. ISBN 978-0123740922.

- Lapan, M. Deep reinforcement learning hands-On: apply modern RL methods to practical problems of chatbots, robotics, discrete optimization, web automation, and more [on line]. 2nd. ed. Packt Publishing, 2020 [Consultation: 19/07/2021]. Available on: <a href="https://ebookcentral.proquest.com/lib/upcatalunya-ebooks/detail.action?docID=6034344">https://ebookcentral.proquest.com/lib/upcatalunya-ebooks/detail.action?docID=6034344</a>. ISBN 978-1838826994.

- Ravichandiran, S. Deep Reinforcement Learning with Python: Master classic RL, deep RL, distributional RL, inverse RL, and more with OpenAI Gym and TensorFlow [on line]. 2020. Packt Publishing, 2020 [Consultation: 19/10/2021]. Available on: <a href="https://ebookcentral.proquest.com/lib/upcatalunya-ebooks/detail.action?docID=6362643">https://ebookcentral.proquest.com/lib/upcatalunya-ebooks/detail.action?docID=6362643</a>. ISBN 9781839215599.

- Mukherjee, B. Optical WDM networks. New York: Springer, 2006. ISBN 0387290559.

### **RESOURCES**

#### **Other resources:**

Tutorial material on basic topics about optical communications, as the basic structure of optical fibers, etc. will be offered to those students who may request or need it.