GENERAL INFORMATION

Course information	
Name	IIoT-Cloud Communications
Code	DEA-MIC-513
Main program	Official Master's Degree in Industrial Engineering
Offered in	Máster Universitario en Ingeniería Industrial + Máster en Industria Conectada [2nd year]
Level	Official Master's Degree
Semester	1st (Fall)
Credits	6.0 ECTS
Type	Elective (MII), Compulsory (MIC)
Department	Electronics, Control and Communications
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COURSE SPECIFIC INFORMATION

Contextualization of the course

Contribution to the professional profile of the degree

With economies of scale for sensors and other devices and the steady improvement in communication infrastructure, in the new industrial operation practice many connected devices (IIoT) report information from ubiquitous locations. The collected data are stored in databases and data warehouses which are more and more commonly hosted in the Cloud, where the information they contain is extracted and used to improve companies' efficiency.

This new context requires a fast, reliable, and secure communication concept. In this course, we will thoroughly review the most important concepts, protocols, and frameworks so that students are able to understand and implement the technology that supports the operation of a growing number of companies today.

By the end of the course, students will:

- Understand how industrial systems based on IIoT and Cloud Computing work.
- Know the most important communication technologies, protocols and frameworks.
- Know today's reference Cloud platforms.

Prerequisites

Being familiar with the fundamentals of networking.

Competences[1] – Objectives

Competences – Máster Universitario en Ingeniería Industrial

General

BA2.	Be able to apply and integrate their knowledge, understanding, scientific foundation and problem-solving skills in new and imprecisely defined environments, including multidisciplinary contexts both in research and in highly specialized professional fields. *Saber aplicar e integrar sus conocimientos, la comprensión de estos, su fundamentación científica y sus capacidades de resolución de problemas en entornos nuevos y definidos de forma imprecisa, incluyendo contextos de carácter multidisciplinar tanto investigadores como profesionales altamente especializados.*
CG1.	Have adequate knowledge of the scientific and technological aspects of mathematical, analytical, and numerical methods in engineering, electrical engineering, energy engineering, chemical engineering, mechanical engineering, mechanics of continuous media, industrial electronics, automation, manufacturing, materials, quantitative management methods, industrial computing, urban planning, infrastructures, etc. *Tener conocimientos adecuados de los aspectos científicos y tecnológicos de: métodos matemáticos, analíticos y numéricos en la ingeniería, ingeniería eléctrica, ingeniería energética, ingeniería química, ingeniería mecánica, mecánica de medios continuos, electrónica industrial, automática, fabricación, materiales, métodos cuantitativos de gestión, informática industrial, urbanismo, infraestructuras, etc.*

[1] Competences in English are a free translation of the official Spanish version.

Competences – Máster en Industria Conectada	
General	
CG1.	Have acquired advanced knowledge and demonstrated, in a research and technological or highly specialized context, a detailed and well-founded understanding of the theoretical and practical aspects, as well as of the work methodology in one or more fields of study. *Haber adquirido conocimientos avanzados y demostrado, en un contexto de investigación científica y tecnológica o altamente especializado, una comprensión detallada y fundamentada de los aspectos teóricos y prácticos y de la metodología de trabajo en uno o más campos de estudio.*
CG2.	Know how to apply and integrate their knowledge, understanding, scientific rationale, and problem-solving skills to new and imprecisely defined environments, including highly specialized multidisciplinary research and professional contexts. Saber aplicar e integrar sus conocimientos, la comprensión de estos, su fundamentación científica y sus capacidades de resolución de problemas en entornos nuevos y definidos de forma imprecisa, incluyendo contextos de carácter multidisciplinar tanto investigadores como profesionales altamente especializados.
CG5.	Be able to transmit in a clear and unambiguous manner, to specialist and non-specialist audiences, results from scientific and technological research or state-of-the-art innovation, as well as the most relevant foundations that support them. Saber transmitir de un modo claro y sin ambigüedades, a un público especializado o no, resultados procedentes de la investigación científica y tecnológica o del ámbito de la innovación más avanzada, así como los fundamentos más relevantes sobre los que se sustentan.
CG6.	Have developed sufficient autonomy to participate in research projects and scientific or technological collaborations within their thematic area, in interdisciplinary contexts and, where appropriate, with a high knowledge transfer component. Haber desarrollado la autonomía suficiente para participar en proyectos de investigación y colaboraciones científicas o tecnológicas dentro de su ámbito temático, en contextos interdisciplinares y, en su caso, con una alta componente de transferencia del conocimiento.
CG7.	Being able to take responsibility for their own professional development and their specialization in one or more fields of study. Ser capaces de asumir la responsabilidad de su propio desarrollo profesional y de su especialización en uno o más campos de estudio.
Specific	
CE4.	Have an overview of the characteristics of the IIoT service platforms, as well as the ability to design a data aggregation and processing system, having the ability to select among the different available technological solutions the most suitable for a particular application or service. *Tener una visión general de las características de las plataformas de servicio IIoT, así como la capacidad de diseñar un sistema de agregación y tratamiento de datos, teniendo la capacidad de seleccionar entre las diferentes soluciones tecnológicas disponibles la más idónea para una aplicación o servicio en particular.*

Learning outcomes
By the end of the course students should:
RA1. Understand the benefits of platform virtualization, and the technical evolution that has led to the development of cloud computing platforms.
RA2. Understand the different cloud services that can be offered and have the ability to design an information management solution for these services.
RA3. Design an IIoT solution using a cloud computing platform.
RA4. Analyze and select the most appropriate communication technology depending on the target application or service.
RA5. Understand and distinguish between different options for communication protocols for IoT.
RA6. Understand the different blocks and processes that make up a framework for IoT communication and information processing.
RA7. Be aware of the existing risks in terms of information security on an IoT platform.
RA8. Compare and be able to decide on the choice of Cloud platforms for IIoT.

CONTENTS

Contents
Theory
Unit 1. Introduction
1.1 Motivation. Overview of current impact of IIoT and Cloud Computing in the industry 1.2 Unraveling the protocol stack 1.3 Communications paradigms 1.4 Traditional Industrial Control Systems vs Distributed Control Systems
Unit 2. Hardware platforms for IIoT
2.1 Raspberry Pi 2.2 Arduino 2.3 Other available solutions (ESP32, PIC, Particle) 2.4 Hardware platform comparison. Use cases and design exercises
Unit 3. Communication technologies
3.1 IEEE 802.15.4/Zigbee 3.2 Bluetooth 3.3 Wi-Fi (IEEE 802.11) 3.4 Ethernet (IEEE 802.3) 3.5 PLC (Power Line Communications) 3.6 LPWAN Technologies (LoRa, Sigfox, NB-IoT, LTE-M) 3.7 Communication technologies comparison. Use cases and design exercises
Unit 4. Communication protocols
4.1 MQTT. 4.2 CoAP 4.2 HTTP RESTful API 4.3 DLMS/COSEM 4.4 OPC UA 4.5 Communication protocols comparison. Use cases and design exercises

Unit 5. Virtualization, "Dockerization", and Cloud
5.1 Concept, purpose, and historical evolution 5.2 Virtualization vs Docker: pros and cons 5.3 Cloud Computing: concept and motivation 5.4 Main Cloud types: IaaS, PaaS, and SaaS 5.5 Cloud Computing: advanced features 5.6 Design exercises
Unit 6. Cloud platforms
6.1 Microsoft Azure 6.2 Amazon AWS 6.3 Google Cloud Platform 6.4 Other cloud platforms (FIWARE, IBM Cloud, Thinger.io) 6.5 Cloud platforms comparison
Unit 7. Outlook and industry trends
7.1 SDN 7.2 NFV 7.3 5G 7.4 Edge and Fog Computing
Laboratory
Block I: IIoT connectivity
In this first block of laboratories the students will gain hands-on experience with common IoT hardware platforms, such as Raspberry Pi, Arduino, or SONOFF, communications technologies, such as Wi-Fi or LPWAN, and communications protocols, such as MQTT or RESTful API, as well as with widely used networking tools, such as Wireshark.
Block II: The Cloud
In this second block of laboratories the students will gain hands-on experience with commercial Cloud Computing platforms. The labs will address how to register and track devices in the Cloud, how to implement device-to-cloud and cloud-to-device messaging, as well as more advanced features, such as real-time monitoring, remote management, data visualization or alert generation.
Block III: Final project
This third and last block of laboratories aims to promote and foster students' initiative, autonomy, and creativity. In this last block of labs, the students will devise, design, and develop their own IIoT-Cloud project, putting together the knowledge and skills acquired throughout Blocks I and II. This project will have to meet technical requirements (e.g., involve sensors and actuators, connect, and manage them using the Cloud, take advantage of advanced Cloud features). In addition, the project will have to also address service and business perspectives.

TEACHING METHODOLOGY

General methodological aspects	
Theory and practice will be combined along the course. The professor will explain the basics of the subject and will go in depth in the more important issues with illustrative examples. The students will be grouped in pairs in order to put in practice the proposed methods and techniques in a collaborative way.	
In-class activities	**Competences**
▪ **Lectures**: The lecturer will introduce the fundamental concepts of each chapter, along with some practical recommendations, and will go through worked examples to support the explanation. Active participation will be encouraged by raising open questions to foster discussion and by proposing short application exercises to be solved in class.	CG1, CG2, CG3, CG4, CG5, CG6, CG7, CE4
▪ **Lab sessions:** Under the instructors' supervision, students, divided in small groups, will apply the concepts and techniques covered in the lectures to real problems and will become familiar with technologies used in development of smart solutions in the context of Industry 4.0.	CG1, CG2, CG3, CG4, CG6, CE4
▪ **Tutoring** for groups or individual students will be organized upon request.	–
Out-of-class activities	**Competences**
▪ Personal study of the course material and resolution of the proposed exercises.	CG1, CG2, CE4
▪ Lab session preparation, programming, and reporting.	CG1, CG2, CE4
▪ Development of the final project	CG1, CG2, CE4

STUDENT WORK-TIME SUMMARY

IN-CLASS HOURS		
Lectures	**Lab sessions**	**Assessment**
36	20	4
OUT-OF-CLASS HOURS		
Self-study	**Lab preparation and report writing**	**Project Development**
30	30	60
	ECTS credits:	**6.0 (180 hours)**

EVALUATION AND GRADING CRITERIA

Evaluation activities	Grading criteria	Weight
Continuous evaluation	▪ Understanding of the theoretical concepts. ▪ Ability to search, analyze, sort and structure information. ▪ Oral communication skills.	20%
Final exam	▪ Understanding of the theoretical concepts. ▪ Application of these concepts to problem-solving.	30%
Lab assignments (Blocks I and II)	▪ Application of theoretical concepts to real problem-solving. ▪ Ability to use and develop lab software. ▪ Written communication skills.	20%
Final project (Block III)	▪ Quality of the project implementation. ▪ Oral communication skills.	30%

Grading

Regular assessment

- **Theory** will account for 50%, of which:
  - Continuous evaluation: 20%
  - Final exam: 30%
- **Lab** will account for the remaining 50%, of which:
  - In-class labs report: 20%
  - Final project development: 30%

In order to pass the course, the mark of the Lab must be greater or equal to 5 out of 10 points and the mark of the Theory must be greater or equal to 5 out of 10 points. Otherwise, the final grade will be the lowest of the two marks.

Retake

There will be only a final exam which will account for 100% of the grade. It will include both practical questions and theoretical concepts.

Course rules

- Class attendance is mandatory according to Article 93 of the General Regulations (Reglamento General) of Comillas Pontifical University and Article 6 of the Academic Rules (Normas Académicas) of the ICAI School of Engineering. Not complying with this requirement may have the following consequences:
  - Students who fail to attend more than 15% of the lectures may be denied the right to take the final exam during the regular assessment period.
  - Regarding laboratory, absence to more than 15% of the sessions can result in losing the right to take the final exam of the regular assessment period and the retake. Missed sessions must be made up for credit.
- Students who commit an irregularity in any graded activity will receive a mark of zero in the activity and disciplinary procedure will follow (cf. Article 168 of the General Regulations (Reglamento General) of Comillas Pontifical University).

WORK PLAN AND SCHEDULE[2]

Activities	Date/Periodicity	Deadline
Continuous evaluation activities to review and self-study of the concepts covered in the lectures	Periodically on demand	–
Final exam	Last week	-
Lab sessions	Weekly	–
Review and self-study of the concepts covered in the lectures	Weekly	–
Project preparation	Weekly	Last week

[2] A detailed work plan of the subject can be found in the course summary sheet (see last page). Nevertheless, this schedule is tentative and may vary to accommodate the rhythm of the class.

BIBLIOGRAPHY AND RESOURCES

Basic references

- Slides prepared by the lecturer (available in Moodle).

Complementary references

- A. S. Tanenbaum and D. J. Wetheral, *Computer Networks*, 5th Ed., Pearson, 2013. ISBN-13: 978-8-131-78757-1
- J. Kurose and K. Ross, *Computer Networking: A Top-Down Approach*, 7th Ed., Pearson, 2016. ISBN-13: 978-0-133-59414-0
- U. Raza, P. Kulkarni and M. Sooriyabandara, "Low Power Wide Area Networks: An Overview," in *IEEE Communications Surveys & Tutorials*, vol. 19, no. 2, pp. 855-873, 2017.
- V. Karagiannis, P. Chatzimisios, F. Vázquez-Gallego and J. Alonso-Zarate, "A Survey on Application Layers Protocols for the Internet of Things", in *Transaction on IoT and Cloud Computing*, 2015.
- O. Liberg, et al., *Cellular Internet of Things: From Massive Deployments to Critical 5G Applications*, 2nd Ed., Academic Press, 2019. ISBN-13: 978-0-081-02902-2
- Microsoft Azure official learning material, [Online]. Available: https://docs.microsoft.com/en-us/learn/azure/

Week	Time [h]	Lecture	Laboratory
1	2	Unit 1 (I)	
	2	Unit 1 (II)	
2	2	Unit 2	
	2	Unit 3 (I)	
3	2	Unit 3 (II)	
	2	Unit 3 (III)	
4	2	Unit 4 (I)	
	2	Unit 4 (II)	
5	2		Block I
	2	Unit 4 (III)	
6	2		Block I
	2	Unit 5 (I)	
7	2		Block I
	2	Unit 5 (II)	
8	2		Block I or Block II
	2	Unit 6 (I)	
9	2		Block II
	2	Unit 6 (II)	
10	2		Block II
	2	Unit 6 (III)	
11	2		Block III
	2	Unit 6 (IV)	
12	2		Block III
	2	Unit 7 (I)	
13	2		Block III
	2	Unit 7 (II)	
14	2		Block III
	2	Unit 7 (III)	