ANX-PR/CL/001-01

LEARNING GUIDE

SUBJECT

593000503 - Sensor Networks

DEGREE PROGRAMME

59AH - Master Universitario En Internet Of Things (iot)

ACADEMIC YEAR & SEMESTER

2024/25 - Semester 1

Index

Learning guide

1. Description

1.1. Subject details

Name of the subject	593000503 - Sensor Networks
No of credits	4.5 ECTS
Type	Compulsory
Academic year ot the programme	First year
Semester of tuition	Semester 1
Tuition period	September-January
Tuition languages	English
Degree programme	59AH - Master Universitario en Internet Of Things (Iot)
Centre	59 - Escuela Tecnica Superior De Ingenieria Y Sistemas De Telecomunicacion
Academic year	2024-25

2. Faculty

2.1. Faculty members with subject teaching role

Name and surname	Office/Room	Email	Tutoring hours *
Pedro Jose Lobo Perea	A4202	pedro.lobo@upm.es	Sin horario. TBD
Fco. Javier Ramirez Ledesma (Subject coordinator)	A4410	javier.ledesma@upm.es	Sin horario. TBD

Jesus Rodriguez Molina	A4415	jesus.rodriguezm@upm.es	Sin horario. TBD
Guillermo Azuara De Pablo	A4206	g.azuara@upm.es	Sin horario. TBD

* The tutoring schedule is indicative and subject to possible changes. Please check tutoring times with the faculty member in charge.

3. Prior knowledge recommended to take the subject

3.1. Recommended (passed) subjects

- Embedded Platforms And Communications For Iot

3.2. Other recommended learning outcomes

- Programming and debugging using the C++ or Java language

4. Skills and learning outcomes *

4.1. Skills to be learned

CB06 - Poseer y comprender conocimientos que aporten una base u oportunidad de ser originales en el desarrollo y/o aplicación de ideas, a menudo en un contexto de investigación

CB10 - Que los estudiantes posean las habilidades de aprendizaje que les permitan continuar estudiando de un modo que habrá de ser en gran medida autodirigido o autónomo.

CE.02 - Diseñar y desarrollar redes de sensores integrando nodos heterogéneos con diferentes sistemas de comunicación inalámbricas para desarrollar aplicaciones IoT

CE.03 - Programar dispositivos móviles en diferentes escenarios de aplicación en IoT en las que se recopilan datos del entorno a través de los sensores integrados en los dispositivos móviles.

CE.13 - Analizar el uso de dispositivos y servicios IoT en dominios de aplicación específicos y seleccionar los dispositivos más adecuados para el ecosistema IoT

CG01 - Los alumnos demostrarán tener una visión del estado actual, las necesidades y los problemas que se plantean en el mundo de la IoT, así como de las arquitecturas y estándares más utilizados

CG02 - Los alumnos serán capaces de aplicar métodos y tecnologías avanzadas que les permitan abordar necesidades y problemas en aplicaciones IoT

CT.01 - Capacidad de uso de la lengua inglesa para el trabajo en contextos internacionales

CT.02 - Capacidad para el trabajo en grupo y dirigir, organizar y supervisar equipos multidisciplinares.

4.2. Learning outcomes

RA39 - To combine the development tools for the integration of the components of a sensor network in IoT environments

RA37 - To build custom sensor nodes tailored to the processing requirements/needs of a given problem.

RA38 - To establish the criteria for the selection and integration into a hardware platform of the required wireless technologies and communication protocols for building IoT applications

* The Learning Guides should reflect the Skills and Learning Outcomes in the same way as indicated in the Degree Verification Memory. For this reason, they have not been translated into English and appear in Spanish.

5. Brief description of the subject and syllabus

5.1. Brief description of the subject

A sensor network is composed of several sensor nodes that communicate among them to build up homogeneous or heterogeneous networks, aiming at sensing information and acting accordingly in a wide physical environment. This course tackles the configuration and implementation of this type of networks, studying the most common technologies, protocols and architectures used. To do so, the building process of custom, high-performance sensor nodes and advanced wireless technologies for IoT are analyzed, considering performance and power consumption factors.

5.2. Syllabus

1. General Communication Model Introduction
   1.1. Context description
   1.2. Challenges
   1.3. Existing models
   1.4. Communications commercial IoT solutions overview
2. Low-power wide-area wireless communications
   2.1. Lora/LoraWAN
   2.2. Sigfox
   2.3. Others (LTE-MTC, NB-IoT, Weightless SIG...)
3. Network interoperability
   3.1. Interoperability models.
   3.2. Gateways
4. Short-range wireless communications
   4.1. IEEE 802.15.4, ZigBee, 6LoWPAN, routing protocols (RPL, AODV)
   4.2. Others (Bluetooth LE,...)
5. Sensor networks practical design methodology
   5.1. Processing requirements
   5.2. Node type, platform and network selection
   5.3. Interoperability requirements
   5.4. Development and test tools
6. Project 1. Embedded wireless sensor design and integration use case
7. Project 2. Short-range wireless communications and interoperability use case

6. Schedule

6.1. Subject schedule*

Week	Type 1 activities	Type 2 activities	Distant / On-line	Assessment activities
1	**Lesson1. General Communication Model Introduction** Duration: 02:00 Lecture **Lesson 2. Low-power wide-area wireless communications** Duration: 03:00 Lecture	**Project 1. Embedded wireless sensor design and integration use case** Duration: 02:00 Laboratory assignments		
2	**Lesson 3. Network interoperability** Duration: 02:00 Lecture	**Project 1. Embedded wireless sensor design and integration use case** Duration: 05:00 Laboratory assignments		
3	**Multiple Choice Test 1** Duration: 00:30 Additional activities	**Project 1. Embedded wireless sensor design and integration use case** Duration: 03:30 Laboratory assignments **Project 1 Assessment** Duration: 03:00 Additional activities		**Multiple Choice Test 1** Written test Progressive assessment Presential Duration: 00:30 **Project 1. Embedded wireless sensor design and integration use case assessment** Problem-solving test Progressive assessment Presential Duration: 03:00
4	**Lesson 4. Short-range wireless communications** Duration: 03:00 Lecture **Challenge.** Duration: 00:15 Challenge-based learning **Thinking design** Duration: 00:15 Design thinking	**Project 2. Short-range wireless communications and interoperability use case assessment** Duration: 03:30 Laboratory assignments		
5	**Lesson 4. Short-range wireless communications** Duration: 01:30 Lecture	**Project 2. Short-range wireless communications and interoperability use case assessment** Duration: 01:30 Laboratory assignments		

6	**Lesson 5. Sensor networks practical design methodology** Duration: 01:30 Lecture	**Project 2. Short-range wireless communications and interoperability use case assessment** Duration: 04:00 Laboratory assignments		
7	**Challenge/Use case design. Non-retakeable assessment.** Duration: 02:00 Additional activities	**Project 2. Short-range wireless communications and interoperability use case assessment** Duration: 01:30 Laboratory assignments		**Challenge/Use case design. Non-retakeable assessment.** Group presentation Progressive assessment Presential Duration: 02:00
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				**Project 1. Embedded wireless sensor design and integration use case assessment (recovery when needed)** Problem-solving test Global examination Presential Duration: 01:30 **Project 2. Short-range wireless communications and interoperability use case assessment. Design, development and deployment of a sensors network.** Problem-solving test Progressive assessment and Global Examination Presential Duration: 03:00 **Multiple Choice Test 2** Written test Progressive assessment and Global Examination Presential Duration: 00:30

Depending on the programme study plan, total values will be calculated according to the ECTS credit unit as 26/27 hours of student face-to-face contact and independent study time.

7. Activities and assessment criteria

7.1. Assessment activities

7.1.1. Assessment

Week	Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
3	Multiple Choice Test 1	Written test	Face-to-face	00:30	9%	0 / 10	CB10 CG01 CT.01 CE.13
3	Project 1. Embedded wireless sensor design and integration use case assessment	Problem-solving test	Face-to-face	03:00	35%	5 / 10	CB06 CB10 CG01 CG02 CT.01 CT.02 CE.02 CE.03 CE.13
7	Challenge/Use case design. Non-retakeable assessment.	Group presentation	Face-to-face	02:00	10%	0 / 10	CB10 CG01 CG02 CT.01 CT.02 CE.13
17	Project 2. Short-range wireless communications and interoperability use case assessment. Design, development and deployment of a sensors network.	Problem-solving test	Face-to-face	03:00	35%	5 / 10	CB06 CB10 CG01 CG02 CT.01 CT.02 CE.02 CE.03 CE.13
17	Multiple Choice Test 2	Written test	Face-to-face	00:30	11%	0 / 10	CB10 CG01 CT.01 CE.13

7.1.2. Global examination

Week	Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
17	Project 1. Embedded wireless sensor design and integration use case assessment (recovery when needed)	Problem-solving test	Face-to-face	01:30	35%	5 / 10	CB06 CB10 CG01 CG02 CT.01 CT.02 CE.02 CE.03 CE.13
17	Project 2. Short-range wireless communications and interoperability use case assessment. Design, development and deployment of a sensors network.	Problem-solving test	Face-to-face	03:00	35%	5 / 10	CB06 CB10 CG01 CG02 CT.01 CT.02 CE.02 CE.03 CE.13
17	Multiple Choice Test 2	Written test	Face-to-face	00:30	11%	0 / 10	CB10 CG01 CT.01 CE.13

7.1.3. Referred (re-sit) examination

Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
Course projects exam	Problem-solving test	Face-to-face	04:00	70%	5 / 10	CB06 CB10 CG01 CG02 CT.01 CT.02 CE.02 CE.03 CE.13
Multiple choice exam	Written test	Face-to-face	01:00	20%	0 / 10	CB10 CG01 CT.01 CE.13

7.2. Assessment criteria

The final mark for each student in this course will be a number between 0 and 10 points. The course is passed if the mark is equal or above 5 points.

Progressive assessment is based on the following components:

- Two quiz-type exam (and/or short answer questions) that assess **theoretical contents** and may contain questions related to the technologies, platforms, software used in the practical project. The second exam may contain questions from the presentations and/or discussion of the "Challenge" and the "Design of a use case". They are called "Test 1" and "Test 2", evaluating:
  Test 1: Lessons 1, 2 and 3 and the preliminary concepts used in Project 1.
  Test 2: Lessons 4 and 5 and the preliminary concepts used in Project 2. Some questions may relate to the challenges presented by the students (and/or commented on in the subsequent discussion).

- Assesment of two **practical project**s, For each project, the correct functional performance of the project is reviewed, as well as its correctness at the design or programming level. It may include, as part of the evaluation of the practical project, written questions (test type and/or short answer) related to the project or technologies used in it. The grade for the functional part, design and programming of the project is common to all members of the working group, but the final grade (based on this common grade), will be modulated on the basis of the result of the written questions relating to the knowledge of the project that each student demonstrates, so that the final grade of the project in which this questions are carried out will therefore be individualised. They are called "Project 1" and "Project 2":
- Project 1: Embedded wireless sensor design and integration use case. Students will have to integrate the Platform use case developed in the subject Embedded Platforms and Communications for IoT in the previous two-month period. Lessons 1, 2 and 3 and the preliminary concepts are applied in Project 1.
- Project 2: Short-range wireless communications and interoperability use case.A wireless sensor network is developed and deployed.

- A "**Challenge**" and a "**Design of a use case**". The work is carried out in groups. This component consists of a technological research work of the student's choice. And also a design of a use case following a "Design Thinking" criterion in which the group of students raises most of the requirements and presents its solution. It is assessed by means of an oral presentation of the work carried out. There will also be a debate

after the presentations, and questions or aspects raised by students or teachers during the presentations and/or debate may form part of the theory exam of the subject. Due to its characteristics, this test cannot be retaken (made up) and will take place on the scheduled day only. If this assessment is not taken, the maximum mark for the ordinary and extraordinary exams will be 9.0 points. In the ordinary and extraordinary exams, the grade obtained in this part of the assessment will be recovered in order to calculate the final grade.

The course grade will be composed of the following elements:

- Multiple choice exams: 20% (2 points)
  - Test 1: 9% (0.9 points)
  - Test 2: 11% (1.1 points)

- Assessment of the course Projects: 70% (7 points)
  - Project 1: 35% (3.5 points)
  - Project 2: 35% (3.5 points)
- A Challenge + Use-case design: 10% (1 point).

Any student who completes at least one of the assessment activities or submits at least one of the practical assignments will be considered 'present' for the course and will receive the appropriate numerical mark. As the practical work is carried out in pairs, if a student does not wish to be considered 'present', he/she must expressly inform the laboratory teacher prior to the delivery and his/her name must not appear on any of the materials making up the delivery.

If a student does not achieve the minimum mark (or does not participate) in any of the assessment activities for which the minimum mark has been set, his/her mark in the assessment call will be the minimum mark between 4 and the one that can be calculated from the assessment activities carried out.

Global ordinary examination

In addition to the assessment of test 2 and project 2 which, together with the previosly obtained grade from 'Challenge" + "Use-case design' (non-retakeable) assessment, account for more than 51% of the grade for the course, the assessment of project 1 can be made up, as this assessment requires a minimum grade.

Global extraordinary examination

The final extraordinary examination will consist of the following components:

- Course projects exam: it is a practical exam of the two developed projects.
- A multiple choice exam, evaluating all the contents of the two continuous assessment multiple choice tests (Test 1 and Test 2). It may also include questions related to the contents exposed/discussed at the challenge/use-case design assessment.

The grade will be composed of the following elements:

- Course projects exam: 70% (7 points)
- Multiple choice exam: 20% (2 points)
- Challenge/use-case design assesment (non-retakeable assessment: obtained on the day scheduled for this assessment): 10% (1 point).

Additional considerations

The solution to the theoretical quiz type tests will not be published, as this part of the exams is based on a question pool (which is revised each year) and the specific questions may vary between students.
Any student interested in the resolution of any part of the exams and practicals will be able to consult in tutorials and in the exam revision processes.

The solution of the projects will not be published, as it may have different results from each group of students, and it is usually used for several consecutive courses (although with some variations) as it requires specialised hardware, so publishing a reference solution would most likely negatively affect the realisation of the projects in subsequent courses. In any case, any interested student can consult and get feedback on the solution of any part of their exam or their specific project, either in tutorials or in the exam revision processes. In addition, when each part of the project is presented, a broad guide to the process and materials to be incorporated into the system that the student is incrementally building is provided, so that, in reality, the solution to the project is presented beforehand as a guide to carry it out.

8. Teaching resources

8.1. Teaching resources for the subject

Name	Type	Notes
Personal computer	Equipment	Personal computer with Internet connection for carrying out practical exercises.
Subject Moodle based web site	Web resource	UPM web site based on Moodle where short technical documents, bibliographic resources, practical exercises instructions and subject slides will be published. Several educational forums will be also available for discussions.
Networked sensors (IoT Platform)	Equipment	The sensors and communication platform previously studied in the subjects "Embedded systems and IoT devices"
Perry Lea. Internet of Things for Architects	Bibliography	Perry Lea, Internet of Things for Architects. Packt Publishing Ltd. 2018
David Hanes et al. "IoT Fundamentals: Networking Technologies, Protocols, and Use Cases for the Internet of Things".	Bibliography	David Hanes et al. "IoT Fundamentals: Networking Technologies, Protocols, and Use Cases for the Internet of Things". Cisco Press. 2017
Libelium Waspmote node, and sensors, and communication modules	Equipment	Equipment used in Project 2. http://www.libelium.com/products/waspmote/
Designing Embedded Systems and the Internet of Things (IoT) with the ARM mbed. Perry Xiao	Bibliography	Designing Embedded Systems and the Internet of Things (IoT) with the ARM mbed. Perry Xiao. 2018 First Edition. ISBN: 978-1119364047

9. Other information

9.1. Other information about the subject

Timetable of this guide

The timetable of activities in this guide should be understood as planning the order and duration of the subjects and activities, but does not take into account circumstances such as public holidays, mid-week start of classes, days with changed teaching activity to match the number of lessons on each day of the week, etc. A detailed timetable will be published on the Moodle site of the subject with the lesson plan that takes these details into account.

Publication of the solutions to the assessment tests

The solutions to the theoretical tests will not be published, as this part of the exams is based on a bank of questions (which is revised each year) and each student may receive different questions. Therefore, it is not feasible to publish the solution of this part of the exam, as it may be different for each student. The solution of the laboratory practicals will not be published, since the practicals are usually used for several consecutive courses, and the publication of a reference solution would most likely negatively affect the performance of the students in subsequent years. In any case, any interested student can consult and obtain feedback on the solution of any part of his or her exam or specific practical work, either in personal tutorials or in the exam revision process.

Project-based learning teaching modality

For the practical part of the course, the project-based teaching method is used. For this purpose, the basics of the subject are first presented in traditional classroom lectures, followed by didactic materials in the course Moodle, presentations and references to guides available online, all of which are applied incrementally to build the system proposed at the beginning of the course.

Challenge-based learning teaching mode

A technological challenge will be proposed, which the group of students will choose and present on the date set aside for this purpose. Once the challenge has been set, it is developed by the group of students in a non-attendance-based way.

Teaching modality of learning based on design thinking

A use case is presented, in which the group of students chooses and presents a majority of its requirements and proposes a design solution. It will be presented on the date set aside for this purpose. Once the case has been proposed, its development is carried out by the group of students.

Sustainable development objectives

The subject enables students to apply previously acquired networking and engineering concepts, integrating concepts of computer networks, sensors, and systems in a cross-disciplinary way so that they can design, configure and manage wireless sensor networks. In this way, this subject is able to contribute to the Sustainable Development Goals (SDG) 4 and 9 of the United Nations, trying to increase, as far as possible, the number of people with the professional and technical skills necessary to access employment and entrepreneurship (Target 4.4), to ensure that students acquire the theoretical and practical knowledge necessary to promote sustainable developments (Target 4.7) and to promote the preparation of professionals capable of developing reliable, sustainable, resilient and quality infrastructures (Target 9.1).

Furthermore, the use of paper in the course has been completely suppressed. All documentation is provided in electronic format. All student submissions are in electronic format. In line with UN SDG 12 to ensure sustainable consumption and production patterns.

In summary, the subject relates to SDGs 4, 9 and 12 (ODS4, ODS9 y ODS12):
Sub-goal 4.4: Substantially increase the number of young people and adults who have the vocational and technical skills needed to access
Sub-goal 4.4: Substantially increase the number of youth and adults who have the vocational and technical skills needed for employment and entrepreneurship.
Sub-target 9.1: Develop reliable, sustainable, resilient and quality infrastructure.
Sub-target 12.2: Achieve by 2030 the sustainable management and efficient use of natural resources
Sub-target 12.5: By 2030, significantly reduce waste generation through prevention, reduction, recycling and reuse activities