ANX-PR/CL/001-01

LEARNING GUIDE

SUBJECT

93000924 - Mobile Communications: 4g And Beyond

DEGREE PROGRAMME

09AT - Master Universitario En Teoria De La Señal Y Comunicaciones

ACADEMIC YEAR & SEMESTER

2024/25 - Semester 1

Index

Learning guide

1. Description

1.1. Subject details

Name of the subject	93000924 - Mobile Communications: 4G And Beyond
No of credits	3 ECTS
Type	Optional
Academic year ot the programme	First year
Semester of tuition	Semester 1
Tuition period	September-January
Tuition languages	English
Degree programme	09AT - Master Universitario en Teoria de la Señal y Comunicaciones
Centre	09 - Escuela Tecnica Superior De Ingenieros De Telecomunicacion
Academic year	2024-25

2. Faculty

2.1. Faculty members with subject teaching role

Name and surname	Office/Room	Email	Tutoring hours *
Jose Manuel Riera Salis	C-430	jm.riera@upm.es	Sin horario. Appointment arranged by email
Luis Mendo Tomas (Subject coordinator)	C-425	luis.mendo@upm.es	Sin horario. Appointment arranged by email

* 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

The subject - recommended (passed), are not defined.

3.2. Other recommended learning outcomes

- Knowledge of array processing and MIMO systems

- Fundamentals of Mobile Communications

- Working knowledge of Matlab

- Fundamentals of wireless propagation

- Fundamentals of Digital Communications

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

CB07 - Que los estudiantes sepan aplicar los conocimientos adquiridos y su capacidad de resolución de problemas en entornos nuevos o poco conocidos dentro de contextos más amplios (o multidisciplinares) relacionados con su área de estudio

CB08 - Que los estudiantes sean capaces de integrar conocimientos y enfrentarse a la complejidad de formular juicios a partir de una información que, siendo incompleta o limitada, incluya reflexiones sobre las responsabilidades sociales y éticas vinculadas a la aplicación de sus conocimientos y juicios

CB09 - Que los estudiantes sepan comunicar sus conclusiones y los conocimientos y razones últimas que las sustentan a públicos especializados y no especializados de un modo claro y sin ambigüedades

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

CE01 - Analizar y aplicar técnicas para el diseño y desarrollo avanzado de equipos y sistemas, basándose en la teoría de la señal y las comunicaciones, en un entorno internacional

CE03 - Valorar y contrastar la utilización de las diferentes técnicas disponibles para la resolución de problemas reales dentro del área de teoría de la señal y comunicaciones.

CT01 - Capacidad para comprender los contenidos de clases magistrales, conferencias y seminarios en lengua inglesa

CT03 - Capacidad para adoptar soluciones creativas que satisfagan adecuadamente las diferentes necesidades planteadas

CT04 - Capacidad para trabajar de forma efectiva como individuo, organizando y planificando su propio trabajo, de forma independiente o como miembro de un equipo

CT05 - Capacidad para gestionar la información, identificando las fuentes necesarias, los principales tipos de documentos técnicos y científicos, de una manera adecuada y eficiente

CT06 - Capacidad para emitir juicios sobre implicaciones económicas, administrativas, sociales, éticas y medioambientales ligadas a la aplicación de sus conocimientos

4.2. Learning outcomes

RA33 - To know 4G mobile communication systems in detail

* 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

In this course the student will learn the fundamentals of modern mobile communication systems, and obtain insight into how current 4G and 5G cellular systems work and are designed.

The course relies on some basic concepts related to digital communication, multi-antenna transmission and wireless propagation, which are assumed to be known.

It begins by reviewing a set of fundamental techniques used in modern systems. The LTE and LTE-A systems are then described with some detail. The description focuses on the radio interface, and covers not only aspects contained in the specifications, but also radio resource management algorithms and methods commonly used by LTE operators. Similarly, an outlook of the NR system is given, and its main technical features are discussed.

Radio network planning techniques applied in these systems are then discussed. This requires the introduction of some notions related to simulation of wireless networks, which is essential to network planning. Based on this, link-level and system-level simulation techniques are presented, with a focus on how they are used in radio network planning for the described systems.

5.2. Syllabus

1. Introduction
    1.1. Basic concepts related to mobile communications
    1.2. Evolution of mobile communication systems. Generations of technologies
2. Fundamentals of modern mobile communication systems
    2.1. Multipath propagation
    2.2. Distortion effects produced by multipath. OFDM
    2.3. Overview of MIMO: diversity and spatial multiplexing
    2.4. Link adaptation
    2.5. Opportunistic user scheduling
3. LTE and LTE-A: system description
    3.1. Origin of LTE. Design targets

3.2. Network architecture

3.3. Radio interface. General characteristics

3.4. Channels in the radio interface

3.5. Physical-layer processing. MIMO transmission

3.6. Radio resource management: rate adaptation, power control, user scheduling

4. Outlook of 5G technologies and standardization

4.1. Visions of 5G

4.2. Use cases and deployment

4.3. Radio Access Technologies for 5G

4.4. Introduction to the 5G New Radio (NR) standard

5. Radio network planning

5.1. Radio network planning. Simulation

5.2. Approximate planning. Link budget. Capacity

6. Link-level aspects

6.1. Link- to system-level interface in OFDM systems

6.2. Multipath channel models

6.3. Link-level simulation

6.4. Link adaptation algorithms

7. System-level aspects

7.1. Monte Carlo simulations

7.2. System-level simulation

7.3. Scheduling algorithms

7.4. Frequency reuse techniques. Interference coordination

7.5. Network optimization

6. Schedule

6.1. Subject schedule*

Week	Type 1 activities	Type 2 activities	Distant / On-line	Assessment activities
1	**Introduction. Chapter 1** Duration: 02:00 Lecture			
2	**Chapter 2** Duration: 02:00 Lecture			
3	**Chapter 2** Duration: 02:00 Lecture			
4	**Chapter 2** Duration: 01:00 Lecture **Chapter 3** Duration: 01:00 Lecture			
5	**Chapter 3** Duration: 02:00 Lecture			
6	**Chapter 4** Duration: 02:00 Lecture			
7	**Chapter 4** Duration: 02:00 Lecture			
8	**Chapter 5** Duration: 02:00 Lecture			
9	**Chapter 5** Duration: 01:00 Lecture **Chapter 6** Duration: 01:00 Lecture			
10	**Chapter 6** Duration: 02:00 Lecture			
11	**Chapter 6** Duration: 02:00 Lecture			

12	**Chapter 6** Duration: 01:00 Lecture **Chapter 7** Duration: 01:00 Lecture			
13	**Chapter 7** Duration: 02:00 Lecture **Submission of assignment: Overview and critical assessment of a selected paper** Duration: 01:00 Additional activities			**Submission of assignment: Overview and critical assessment of a selected paper** Individual work Progressive assessment and Global Examination Not Presential Duration: 01:00
14	**Chapter 7** Duration: 02:00 Lecture **Submission of assignment: student work on a specific subject** Duration: 01:00 Additional activities			**Submission of assignment: student work on a specific subject** Individual work Progressive assessment and Global Examination Presential Duration: 01:00
15				
16				
17	**Examination** Duration: 02:00 Additional activities			**Examination** Written test Progressive assessment and Global Examination Presential Duration: 02:00

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
13	Submission of assignment: Overview and critical assessment of a selected paper	Individual work	No Presential	01:00	15%	/ 10	CB06 CB07 CB08 CB09 CB10 CT01 CT04 CT05 CT06 CE01
14	Submission of assignment: student work on a specific subject	Individual work	Face-to-face	01:00	20%	/ 10	CB06 CB07 CB08 CB09 CB10 CT01 CT03 CT04 CT05 CT06 CE01 CE03
17	Examination	Written test	Face-to-face	02:00	65%	4 / 10	CB06 CB07 CB08 CB09 CB10 CT01 CT03 CT04 CT05 CT06 CE01 CE03

7.1.2. Global examination

Week	Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
13	Submission of assignment: Overview and critical assessment of a selected paper	Individual work	No Presential	01:00	15%	/ 10	CB06 CB07 CB08 CB09 CB10 CT01 CT04 CT05 CT06 CE01
14	Submission of assignment: student work on a specific subject	Individual work	Face-to-face	01:00	20%	/ 10	CB06 CB07 CB08 CB09 CB10 CT01 CT03 CT04 CT05 CT06 CE01 CE03
17	Examination	Written test	Face-to-face	02:00	65%	4 / 10	CB06 CB07 CB08 CB09 CB10 CT01 CT03 CT04 CT05 CT06 CE01 CE03

7.1.3. Referred (re-sit) examination

Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
Examination	Written test	Face-to-face	02:00	65%	4 / 10	CB06 CB07 CB08 CB09 CB10 CT01 CT03 CT04 CT05 CT06 CE01 CE03
Submission of assignment: Overview and critical assessment of a selected paper	Individual work	Face-to-face	01:00	15%	/ 10	CB06 CB07 CB08 CB09 CB10 CT01 CT04 CT05 CT06 CE01
Submission of assignment and presentation: student work on a specific subject	Individual work	Face-to-face	01:00	20%	/ 10	CB06 CB07 CB08 CB09 CB10 CT01 CT03 CT04 CT05 CT06 CE01 CE03

7.2. Assessment criteria

Students will be qualified through continuous evaluation by default. According to the *Normativa de Evaluación del Aprendizaje de la Universidad Politécnica de Madrid*, students willing to renounce to continuous evaluation must complete the Moodle task entitled "Renounce to continuous evaluation" within 5 weeks after the beginning of the course (deadline will be announced in Moodle).

Evaluation will assess if students have acquired all the competences of the subject. Thus, evaluation through extraordinary (resit) assessment will use the same types of evaluation techniques used in the ordinary evaluation (EX, ET, TG, etc).

Evaluation will be based on the following activities, all of which are compulsory. This applies to the continuous assessment and final assessment modalities, as well as to the extraordinary examination. The final mark will be an average with the specified weights.

1. Overview and critical assessment of a selected paper: 15%.
    - The student should hand in an overview and critical assessment of one of the papers provided during the course, or some other chosen by them.
2. Student work on a specific subject: 20%.
    - The student should do the course practice work and hand in a summary of results. The work may consist in doing some simulation work; or in studying a topic in depth and handing in an essay, discussing additional details not covered in the course.
    - The topic will be selected from a list provided by the instructor, or will be selected by the students based on their interests.
    - The work will be presented in class or to the professor. The presentation will highlight the most significant parts of the work
3. Final Exam: 65%. Minimum mark: 4.0
    - This will be a written examination about the materials covered by the course.

8. Teaching resources

8.1. Teaching resources for the subject

Name	Type	Notes
Dahlman, 2014	Bibliography	E. Dahlman, Stefan Parkvall and Johan Sköld, 4G: LTE / LTE-Advanced for Mobile Broadband, second edition. Academic Press, 2014.
Tse, 2015	Bibliography	D. Tse and P. Viswanath, Fundamentals of wireless communications. Cambridge University Press, 2005
Johnson, 2012	Bibliography	Chris Johnson, LTE in bullets, second edition. 2012
Sesia, 2011	Bibliography	Stefania Sesia, Matthew Baker and Issam Toufik, LTE - The UMTS Long Term Evolution: From Theory to Practice, second edition. John Wiley and sons, 2011.
Holma, 2011	Bibliography	Harri Holma and Anti Toskala (editors), LTE for UMTS: Evolution to LTE-Advanced, second edition. John Wiley and sons, 2011
Rappaport, 2015	Bibliography	Theodore S. Rappaport, Robert W. Heath Jr., Robert C. Daniels, James N. Murdock. "Millimeter Wave Wireless Communications". Prentice Hall, 2015
Wyglinski, 2010	Bibliography	Alexander M. Wyglinski, Maziar Nekovee, Y. Thomas Hou, (editors), "Cognitive Radio Communications and Networks", Elsevier, 2010.
Various papers	Bibliography	Several papers will be recommended during the course

Mathworks, 2016	Equipment	Matlab LTE System Toolbox. http://es.mathworks.com/products/lte-system/
Dahlman, 2018	Bibliography	Erik Dahlman, Stefan Parkvall, Johan Sköld. 5G NR: The Next Generation Wireless Access Technology