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

2020/21 - 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	2020-21

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

- Fundamentals of Mobile Communications

- Working knowledge of Matlab

- Knowledge of array processing and MIMO systems

- 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, obtain insight into how current 4G cellular systems work and are designed, and acquire basic knowledge of what future systems will be like.

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 presenting a set of fundamental techniques used in modern systems.

The LTE and LTE-A systems are then described with considerable 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.

Radio network planning techniques applied in these systems are also discussed. This requires the introduction of some notions related to simulation of wireless networks, which is essential to network planning. Planning techniques are then presented, including advanced features such as partial frequency reuse and dynamic interference coordination.

Lastly, an outlook of future 5G systems is given, and their main technical features are discussed.

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. Modulation, coding, and MIMO transmission
   3.6. Radio resource management: rate adaptation, HARQ with combining, power control, user scheduling
4. LTE and LTE-A: radio network planning
   4.1. Radio network planning. Simulation
   4.2. Approximate planning. Link budget. Capacity
5. Link-level aspects
   5.1. Link- to system-level interface in OFDM systems
   5.2. Multipath channel models
   5.3. Link-level simulation
   5.4. Link adaptation algorithms
6. System-level aspects
   6.1. Monte Carlo simulations
   6.2. System-level simulation

6.3. Scheduling algorithms

6.4. Frequency reuse techniques. Interference coordination

6.5. Network optimization

7. Outlook of 5G systems

7.1. Visions of 5G

7.2. Use cases and deployment

7.3. Radio Access and Technologies for 5G

7.4. Introduction to the New Radio (NR) standard

6. Schedule

6.1. Subject schedule*

Week	Face-to-face classroom activities	Face-to-face laboratory 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: 01:00 Lecture **Chapter 5** Duration: 01:00 Lecture			
8	**Chapter 5** Duration: 02:00 Lecture			
9	**Chapter 5** Duration: 02:00 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** Individual work Continuous assessment and final examination Not Presential Duration: 01:00
14				**Submission of assignment and presentation: student work on a specific subject** Individual work Continuous assessment and final examination Presential Duration: 01:00
15				
16				
17				**Examination** Written test Continuous assessment and final 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.

* The schedule is based on an a priori planning of the subject; it might be modified during the academic year, especially considering the COVID19 evolution.

7. Activities and assessment criteria

7.1. Assessment activities

7.1.1. Continuous 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	CB08 CB09 CT01 CB07 CB06 CT04 CE01 CT06 CT05 CB10
14	Submission of assignment and presentation: student work on a specific subject	Individual work	Face-to-face	01:00	20%	/ 10	CB08 CB09 CT01 CB07 CT03 CB06 CT04 CE01 CT06 CE03 CT05 CB10
17	Examination	Written test	Face-to-face	02:00	65%	4 / 10	CB08 CB09 CT01 CB07 CT03 CB06 CT04 CE01 CT06 CE03 CT05 CB10

7.1.2. Final 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	CB08 CB09 CT01 CB07 CB06 CT04 CE01 CT06 CT05 CB10
14	Submission of assignment and presentation: student work on a specific subject	Individual work	Face-to-face	01:00	20%	/ 10	CB08 CB09 CT01 CB07 CT03 CB06 CT04 CE01 CT06 CE03 CT05 CB10
17	Examination	Written test	Face-to-face	02:00	65%	4 / 10	CB08 CB09 CT01 CB07 CT03 CB06 CT04 CE01 CT06 CE03 CT05 CB10

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	CB08 CB09 CT01 CB07 CT03 CB06 CT04 CE01 CT06 CE03 CT05 CB10
Submission of assignment: Overview and critical assessment of a selected paper	Individual work	Face-to-face	01:00	15%	/ 10	CB09 CB08 CT01 CB07 CB06 CT04 CE01 CT06 CT05 CB10
Submission of assignment and presentation: student work on a specific subject	Individual work	Face-to-face	01:00	20%	/ 10	CB08 CB09 CT01 CB07 CT03 CB06 CT04 CE01 CT06 CE03 CT05 CB10

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 final assessment will be carried out considering all the evaluation techniques used in continuous evaluation (EX, ET, TG, etc.), and will be celebrated in the exam period approved by Junta de Escuela for the current academic semester and year. Evaluation activities that assess learning outcomes that cannot be evaluated through a single exam can be carried out along the semester.

Extraordinary examination will be carried out exclusively by the final assessment method.

Evaluation will be based on the following activities. 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 indicated 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