UNIVERSITÀ DEGLI STUDI DI PALERMO

DEPARTMENT	Ingegneria
ACADEMIC YEAR	2022/2023
MASTER'S DEGREE (MSC)	ELECTRONICS AND TELECOMMUNICATIONS ENGINEERING (FULLY ONLINE)
SUBJECT	CELLULAR NETWORKS AND 5G
TYPE OF EDUCATIONAL ACTIVITY	B
AMBIT	50362-Ingegneria delle telecomunicazioni
CODE	21519
SCIENTIFIC SECTOR(S)	ING-INF/03
HEAD PROFESSOR(S)	TINNIRELLO ILENIA Professore Ordinario Univ. di PALERMO
OTHER PROFESSOR(S)	
CREDITS	9
INDIVIDUAL STUDY (Hrs)	162
COURSE ACTIVITY (Hrs)	63
PROPAEDEUTICAL SUBJECTS	
MUTUALIZATION	
YEAR	2
TERM (SEMESTER)	1° semester
ATTENDANCE	Not mandatory
EVALUATION	Out of 30
TEACHER OFFICE HOURS	**TINNIRELLO ILENIA** Monday 9:00 12:00 Ufficio del docente, presso il DEIM, secondo piano.

DOCENTE: Prof.ssa ILENIA TINNIRELLO

PREREQUISITES	The course is self-consistent. However, it is recommended to have some basics of signal theory and probability.
LEARNING OUTCOMES	Knowledge and understanding At the end of the class, the student will be able to understand in depth the problems which characterize the design and the optimization of wireless networks and cellular systems, in various application scenarios (voice and data) and under different propagation conditions (line-of-sight, multipath, etc.). In particular, the student will learn the consolidated and emerging solutions for the management of radio resources and mobility, by starting from the review of the GSM/UMTS and 4G/5G standards for cellular systems, and 802.11 standard for WLAN systems. To achieve this goal, the course includes: video-recorded lectures, teacher-led discussions of case studies; exercises and projects; review of scientific papers on emerging research topics. Knowledge and understanding The student will be able to solve some simple design problems for cellular systems based on the utilization of radio propagation models (devised to assess the network coverage) and traffic engineering tools. She/he will be able to design customized protocols and perform context-specific optimizations in various application scenarios. To achieve this goal, the course includes lectures with exemplar design solutions, as well as individual homework. Judgements The student will be stimulated to extrapolate the techniques and the algorithms presented in the course from the relevant contexts and technologies in order to apply/adapt these tools to different wireless systems and application scenarios. She/he will also be able to compare alternative architectures and protocol solutions for wireless networks, by performing some performance evaluations based on simplified models or simulation tools. To achieve this goal, the course offers video lectures with examples of system design solutions, as well as exercises with increasing level of complexity and discussions of case studies with the tutors. Communication skills The student will learn the ability to rationally communicate her/his knowledge about the concepts and methods of the discipline, with a good level of clearness, fluency and correct use of technical language. In particular, she/he will be able to justify the design choices and the application of specific tools for solving the proposed analysis or synthesis problems. To achieve this goal, the student can rely on the video lectures and on the interactions with the tutor. Learning skills The student will be able to read autonomously technical standards and scientific literature about wireless networks, in order to follow the evolutions and trends of wireless technologies and, in particular, to understand the implications of the new physical layers (e.g. full-duplex systems, massive MIMO, etc.) and medium access protocols currently under debate. To achieve this goal, the course includes: video lectures illustrating specific design problems; readings and questionnaires about research papers from the scientific literatures; technical debates on the class forum about emerging topics among student.
ASSESSMENT METHODS	EXAM ORGANIZATION The examination is based on a written test and on the evaluation of the student homework. The grade of the written test is given in the range 0-25, while the grade of the homework in the range 0-5. The final grade is given by the sum of the written test and homework evaluation. The minimum grade to pass the test is 18/30. DESCRIPTION OF THE TESTS The written test includes two parts: a first part focused on the design of simple wireless systems, with some problems about the planning of cellular networks based on radio propagation models and traffic engineering tools; a second part with open and semi-structured questions about all the course contents. The written test lasts 2 hours. The test is devised to evaluate: - The knowledge and understanding levels of radio propagation models and teletraffic tools, with specific applications to the design of cellular systems; - The capability of applying the acquired knowledge to solve autonomously design problems and protocol optimizations; - The ability to communicate knowledge, analyses and conclusions, and justify the design choices. The homework is based on the solution of exercises proposed at the end of

	each teaching module, as well as on the autonomous elaboration of an advanced/research topic (typically about emerging wireless technologies) selected by the student, which is organized in a power-point presentation. The homework allows to assess: - The capability of reading and understanding the research literature and the technology standards related to the course topics; - The ability of reinterpretation of the concepts and interdisciplinary connections, showing evidence for autonomously undertaking further studies or professional activity. LEARNING OUTCOMES In order to provide the overall evaluation, we will estimate the results achieved in the following course objectives. Knowledge and understanding: Evaluation of knowledge, understanding and integration of principles, concepts, methods and techniques of the discipline. Applying knowledge: Evaluation of capabilities in applying theoretical and technical knowledge for tackling and solving problems; evaluation of the autonomy level and originality of proposed solutions. Making judgements: Evaluation of logical, analytical and critical abilities for reaching appropriate judgments and decisions, based on available information and data. Communication skills and learning skills: Evaluation of the ability to communicate knowledge, analysis and conclusions, with a good level of clearness, fluency and correct use of language. GRADES 30-30 and laude: Excellent. Full knowledge and understanding of concepts and methods of the discipline, excellent analytical skills even in solving original problems; excellent communication and learning skills. 27-29: Very good. Very good knowledge and understanding of concepts and methods of the discipline; very good communication skills; very good capability of concepts and methods applications. 24-26: Good. Good knowledge of main concepts and methods of the discipline; discrete communication skills; limited autonomy for applying concepts and methods for solving original problems. 21-23: Satisfying. Partial knowledge of main concepts and methods of the discipline; satisfying communication skills; scarce judgment autonomy. 18-20: Acceptable: Minimal knowledge of concepts and methods of the discipline; minimal communication skills; very poor or null judgement autonomy. Non acceptable: Insufficient knowledge and understanding of concepts and methods of the discipline.
EDUCATIONAL OBJECTIVES	This course provides an overview of wireless networks, based on the presentation of the main technical features characterizing these networks (wireless propagation, interference, mobility), the main approaches and design principles, as well as some specific examples of wide-spread technologies for both cellular systems and wireless local area networks. A first educational objective is understanding radio propagation and traffic generation phenomena in order to identify the system requirements to be used for network design. A second educational objective, is understanding the main features and technical aspects of public cellular systems, with special attention to LTE/5G and 802.11 networks. Finally, a third educational objective is providing methods and approaches for evaluating complex radio systems, by characterizing the interactions between applications, physical layers, MAC layers, in order to be able to design/adapt existing protocols to the emerging network scenarios.
TEACHING METHODS	The course is organized in 6 modules, each one including a set of video lectures (pre-recorded) and a set of e-tivity: More into details, the list of modules is the following one: 1) channel models and simulators (5 hours of video lectures); 2) principles of cellular planning (5 hours of video lectures); 3) GSM/GPRS/UMTS (6.5 hours of video lectures); 4) Modern cellular systems: 4G/5G (5 hours of video lectures); 5) Wireless Local Area Networks: WiFi (5 hours of video lectures); 6) Technologies for Internet-of-Things (5 hours of video lectures). For each module, we propose a set of exercises, questionnaires and virtual laboratorial experiences as additional learning activities, also devised to facilitate the self-assessment of the learning outcomes. We expect that each student will dedicate about 32 hours for these activities. About one half of the activities are proposed as activities to be carried out autonomously by the students, while another half will be supervised or led by the course tutor. More into details, the interactive activities planned for each module are the following one: 1)Laboratory on the usage of radio propagation simulators, such as SEAMCAT

	(3 hours with tutor); exercises (2 hours); 2)Tools for evaluating/simulating outage probability of cellular-like systems (3 hours with tutor); exercise (2 hours); 3)Questionnaires (2 hours); problems on control operation in cellular systems (2 hours); evaluation of handover metrics (1 hour with tutor); 4)Virtual lab on software-defined-radio (2 hours with tutor); virtual lab on OFDM modulation (1 hour with tutor); questionnaires (2 hours); 5)Virtual lab on linux-based WiFi drivers (2 hours with tutor); collaborative projects and questionnaires (3 hours); 6)Virtual lab on IoT platforms (2 hours with tutor); collaborative projects and questionnaires (3 hours). The activities will be organized on the on-line learning platform, also exploiting discussion forums and interactive meetings for the organization of the laboratorial activities. The overall number of hours for the individual study activities is estimated equal to additional 162 hours, which include 32 hours for replaying the video lectures.
SUGGESTED BIBLIOGRAPHY	- Wiley, «From GSM to LTE Advanced», M. Sauter, ISBN-13: 978-1119346869 - Shankar, “Introduction to Wireless Systems”, Wiley, 2001 - Matthew Gast, “802.11 Wireless Networks: The Definitive Guide”, O'Reilly Research papers Lectures slides.

SYLLABUS

Hrs	Frontal teaching
5	Module 1: 2 Radio channel characterization. Propagation and fading models. 3 Network planning concepts: frequency reuse and clustering. Examples of radio coverage simulators.
5	Module 2: 2 Planning of simple cellular systems based on radio coverage requirements: outage probability. 3 Planning of simple cellular systems based on tele-traffic engineering: Erlang B formula and its applications.
7	Module 3: 2 GSM/GPRS/UMTS General Architecture. 1.5 GSM/GPRS Radio Interface 1 UMTS Radio Interface 2 PDP Context and Mobility Management
5	Module 4: 2LTE/5G Architecture. 2OFDM and LTE Physical Layer. 15G opportunities.
5	Module 5: 2WLAN architectures and 802.11a/b/g/n/ac Physical Layer 2 Medium access layer for 802.11: DCF and PCF protocols 1 WiFi evolutions.
5	Module 6: 2 Low-power long range technologies for IoT 3 Low-range technologies for IoT

Hrs	Practice
30	5hours, Cellular radio planning 5 hours, Applications of tele-traffic tools to cellular system design. 5 hours, Control Procedures in 2G/3G Networks 5 hours, Control Procedures and PHY in 4G/5G Networks 5 hours, Configuration of WiFi networks 5 hours, Configuration of IoT networks