MASTEAM

Master’s Degree in Applied Telecommunications & Engineering Management

Scope and Objectives

Telecommunication has evolved from audio and video communication for personal information exchange and entertainment to pervasive data communication in the Mobility and Internet-of-Things era. Currently, telecommunications in general and Internet in particular are major technological drivers, providing solutions for countless applications that were unthinkable just two decades ago. They have transformed the ways we communicate and live.

This master degree is intended for those willing to acquire the skills that will enable them to conceive, design and implement cutting-edge engineering solutions based on the latest telecommunication and Internet technologies in order to improve people’s welfare in a sustainable economy.

Structure

- Total: 60 ECTS
- Mandatory contents: 15 ECTS (courses) + Master Thesis: 12 ECTS
- Optional contents: 33 ECTS - Total optional offer: 42 ECTS

In parenthesis, the number of ECTS

Students must take 15 ECTS in 1A2, 9 ECTS in 1B1 and 9 ECTS in 1B2. Master Thesis is mandatory
Next Generation Wireless Communications and IoT (3 ECTS) - Compulsory

Cutting-edge trends for future applications based on wireless communications

- 4G/5G networks
- Dense cell deployment: Small Cells, Heterogeneous Networks (HetNets), Vertical Handover
- Spectrum management: cognitive networks
- Cooperative communications: Network Coding
- Wireless Sensor Networks (WSN) and Internet of Things

Extended description:

A mobile communication system beyond 4G should support 1000 times higher mobile data volume per area, 10 to 100 times more connected devices, 10 to 100 times higher typical user data rate, 10 times longer battery life for low power devices and 5 times smaller end-to-end latency. This is mainly because mobile communications are evolving to allow any electronic device, not only those carried by humans, wirelessly to connect to the Internet.

This course is mainly about new Radio Access Network (RAN), machines, vehicles, cities & services and health sensors. Covered topics are 4G/5G networks including dense cell deployment, reconfigurable radio for HetNets, the Internet of Things as an evolution of wireless sensor networks, spectrum management and cognitive networks, cooperative communications and network coding, virtual networks and cloud based architectures.

Current RANs and Terminals have been deployed based on the evolution of Cellular Networks maintaining a fixed spectrum allocation and hierarchical structure. Existing technologies which are the base of Next Generation Wireless Communications (NGWC) are analysed, as LTE and LTE-A but also cutting-edge WLAN, WPAN and WMAN, focusing on their Physical, Media Access Control and Logical Link Control (PHY, MAC and LLC) layers.

Future scenarios in radio communications rise to situations where a huge number of devices are located in physical proximity generating large amounts of independent traffic with different requirements sharing the same pool of radio resources in what is known as the Wireless Internet of Things which can be seen as the raising of a new generation of local or wide area Wireless Sensor Networks with coordination and communication entities and group mobility. Cloud Radio Access Network and Cloud Network Virtualisation are seen as a potential evolution of network architecture through the capacity of pooling underlying physical resources or logical elements in a network.

Simultaneously Radio Access systems, services and applications need to be more efficient in terms of energy and spectrum usage, reducing the signaling load, the latency and maximizing the spectrum efficiency, through networks allowing opportunistic access, cognitive radio and White Space Devices through geo-location databases implementing location aware communications and co-primary usage in shared bands.

Vehicles can act as mobile base stations but also as moving sensors. They will become integrate parts of the radio access network, through their capability to relay communication links to other vehicles or to passengers through Intra-Vehicular, Vehicular to Vehicular and Vehicular to Infrastructure communications (InV, V2V, V2I) addressing four main applications: infotainment to passengers, vehicular cloud services, traffic safety and traffic efficiency.
Additionally wearable and implanted devices in people (*Body Area Networks*) will revolutionize health monitoring, wellness and assisted living offering an enhanced interaction with surrounding technologies.

*Intelligent Cooperation* among networks and devices including not only fixed infrastructure but also relays and mobile nodes is the basis of future moving networks where many new concepts in *network coding, relaying, self-organization or opportunistic caching* play an important role to improve throughput, robustness and efficiency. A further step to 5G networks is *Cloud-RAN* (C-RAN) concept with collaborative radio and real-time cloud computing, splitting the BS into a remote Radio Unit (RU) and multiple software-based Digital Units (DU) on a Virtual Machine (VM). This centralized cloud processing in a large cluster of RUs enables *inter-cell interference reduction* and *Coordinated Multi-Point* (CoMP) transmission and reception mechanisms, easing also the *Handover* between RUs

The combination of all the wireless technologies deployed in urban environments are the basis of new *City Services deployment*; optimizing transportation, offering personalized services to citizens and improved management and social services to the community.

**Evaluation Criteria:**

- Students will have to deliver one or more reports regarding its progress.
- A final exam will account for 40% of the final mark.
- Problem solving 30%
- Weekly assignments 30%
Optimization for Applied Engineering Design (3 ECTS) - Compulsory

Description
Applied optimization and heuristic techniques for modelling and solving optimization problems originating from telecommunication and other areas.

Contents
- Optimization with Engineering Applications
- Nature-Inspired Algorithms. Colonies and Swarms
- Biogeography-based techniques

- **Optimization with Engineering Applications**

- **Optimization Heuristics**
  This topic will introduce and discuss heuristic optimization techniques including genetic algorithms, Tabu search, simulated annealing, evolutionary and differential algorithms, and artificial intelligence. Complexity and convergence of the algorithms.

- **Nature-Inspired Algorithms. Colonies and Swarms**
  Nature-Inspired algorithms are motivated by optimization processes that we observe in nature, such as natural selection, species migration, bird swarms, human culture, and bee or ant colonies. Swarm Intelligence is a computational intelligence technique involving the study of collective behavior in decentralized systems.

  The topic considers societal problems of importance to civil and environmental engineers, including those arising in the context of ecology, energy efficient buildings, transportation and logistics, and water and infrastructure systems. Application and case studies: Optimization of Agent-Based Models to simulate real-world systems.

- **Biogeography-based techniques**
  Biogeography includes the study of the distribution of life forms in nature over time and space. It could be used to concern with long-term and large-scale distributions.

Evaluation Criteria:
- Periodic assignments: 30%.
- Students will have to implement one combinatorial or heuristic algorithm, selecting the application area: 30%.
- A final exam will account for 40% of the final mark.
Network Engineering (3 ECTS) - Compulsory

Description

Analysis, modelling and design of large-scale networks, services and systems governed by dynamic, deterministic or random processes.

Contents

- **Introduction to large-scale dynamic systems**
  o Taxonomy, classification.
  o Complex systems. Dynamic systems. Models.
  o Complex systems and randomness. Entropy.
  o Use cases:
    - Time delay models. Resource reservation on real time services.

- **Network models**
  o Use cases:
    - Formation, growth and evolution of a social network.
    - Evaluation of ad-hoc networks.
  o Graph theory and networks. Taxonomy, classification. Large-scale and robustness.
  o Free scale networks.
  o Modelling temporal evolution of network and services. Preferential attachment. Formation, incentives and efficiency.

- **Competitive and cooperative systems**
  o Use cases:
    - Profit maximization. Internet service provider
    - ISP’s routing game
  o Game Theory. Inverse Game Theory. Static (finite and continuous) games.
  o Dominant strategies. Cooperative outcomes: Prisoner’s dilemma.
  o Traffic equilibrium. Pigou example.
  o Strategic network formation.

- **Dynamic systems**
  o Use cases:
    - Propagation of information on social networks.
    - Predator-prey model (Lotka-Volterra) for analysing the evolution of telecommunication services in the telecommunication market.
  o Diffusion and transport.
  o Random walks and diffusion on networks.
  o Dynamical systems with time delay.
  o S-I-R models.

Evaluation Criteria

- 30% Use cases (based on problem solving).
- 30% Weekly assignments.
- 40% Final exam.
Sensors and Interfaces (3 ECTS) - Compulsory

Sensors and their circuit interfaces for monitoring or control systems and man-machine interfaces.

- Signal chain design
- Sensor performance assessment
- Analog sensors and signal conditioning
- Digital sensors and their interfaces

- Signal chain design


- Sensor performance assessment

Sensing methods: primary sensors and MEMS. Static characteristics: sensitivity, resolution, accuracy, nonlinearity. Dynamic characteristics: dynamic sensitivity, time response.

- Analog sensors and signal conditioning


- Digital sensors and their interfaces


Evaluation criteria:

Two short tests (25 % each) plus a final exam (50 %).
ICT-based entrepreneurship (3 ECTS) - Compulsory

New business models based on ICT applications and ecommerce

- Innovation models
- Business models of ICT-based companies
- Customer development. Lean startup concepts
- Canvas analysis
- Process analysis
- Sales for ICT-based startups

- Innovation models:
  Topics: The need of innovation. The innovation process. Tools of generation of ideas. Characteristics of the innovation when high technology is involved. Value analysis. R&D environment.

- Business models of ICT-based companies
  Topics: The concept of business model. Business models: ecommerce, mcommerce, b2b, peer to peer, markets, and so on. The concept and the process of monetarization. Examples and cases.

- Customer development. Lean startup concepts

- Canvas analysis
  Topics: Concept and detailed description: Stakeholder Segments, Value Propositions, Channels, Stakeholder Relationships, Funding, Key Resources, Key Activities, Key Partners, Cost Structure.

- Process analysis
  What a process is. Principal processes. Critical processes. Select the main processes of an activity. Process maps. Include data in the process maps. Obtain the capacity needs from this analysis.

- Sales for ICT-based startups
  Topics: Sales and marketing at the first phases of a company. Different strategies. The management of sales: leads, scores and CRM. Alliances. Sales analysis and forecasting.

Evaluation Criteria:

The students will analyze a case of an existent startup. Five deliverables regarding the main aspects will we presented: business model, customer development, canvas analysis, sales strategy and assessment of the company perspectives. Each deliverable will be assessed and will count for a 10% of the final mark. A final exam will account for the other half.
Optical Networks for Cloud-based Services (3 ECTS)

Short description:

The enabling technologies to be deployed in future optical transport networks to support the expected traffic demands and cloud-based services and applications requirements are discussed. To fully exploit the innovative functionalities provided by the emerging optical technologies, the control architecture to efficiently manage optical transport networks are also introduced.

Topics:

1. Enabling technologies for advanced optical fibre-based networks
   - Evolution towards all-optical WDM-based networks: Integration IP/WDM, OTN, intelligent optical networks
   - Flex-grid optical technology
   - Sub-wavelength/super-channel enabling technologies
   - Tunable optical filters
   - WSS switches (ITU Fixed Grid and Gridless), ROADMs
   - Advanced modulation formats (Modulation Constellations with Multi-level Formats)
   - Elastic and flexible transponders with reconfigurable bit rate, modulation format and wavelength
   - Fiber Multi-core/multi-mode technology

2. Optical systems for cloud computing and data centres interconnects
   - Optical technologies and devices for inter/intra data centres interconnects in support of reduced latency and high throughput.
   - Optical technologies for High Performance Computing (HPC).

3. Enabling optical systems for energy-efficient optical networks
   - Optical devices (transponders, amplifiers, short/long reach optical cards) for sleep-mode operation for energy efficiency.

4. Control/Management plane for optical transport networks
   - Software defined optics, SDN-based architectures for optical transport network technologies.

Evaluation criteria:

- Final exam (40%)
- Individual presentations/reports on the topics of the course (60%)
Internet of Things and Ubiquitous IP (3 ECTS)

Description
Technologies for connecting the physical world to the Internet, and their applications in smart environments.

Contents
- Internet evolution
- Internet of Things: technologies and applications
- Wireless experience enhancement
- Mobility support

- Internet evolution

This topic provides an overview of how the Internet has evolved since its origin, highlighting the motivation, fundamentals and near-future use cases of IPv6 (the long-term solution for Internet connectivity). Limitations of the legacy Internet architecture are shown, and possible solutions are given.

- Internet of Things: technologies and applications

This topic focuses on constrained nodes and networks, the new IP-based protocol suite for their connection to the Internet, and the smart applications enabled by this technology in a wide range of domains such as cities, homes, buildings, agriculture, health, vehicles, etc.

- Wireless experience enhancement

This topic provides management, autoconfiguration and analysis tools for wireless networks performance improvement, as well as end-to-end protocol solutions and optimizations for wireless Internet access.

- Mobility support

This topic provides the analysis tools, protocols and architectures for supporting the mobility of things, people and vehicles for network/Internet connectivity, and enabling cutting-edge applications in several areas. The topic includes the impact of network mobility on network parameters and their configuration.

Evaluation Criteria
- Students will have to deliver one or more reports regarding their progress.
- A final exam will account for half the final mark.
5G Mobile Network Planning (3 ECTS)

Realistic mobile network planning considering scientific challenges towards 5G Mobile Communications.

- mobile system planning: coverage and capacity optimization
- Green networks: spectrum and energy efficiency
- HetNets
- Self-Organizing Networks (SON)

Detailed content:

This course is oriented to analyze all those parameters and algorithms determining a realistic network deployment through the use of GIS facilities oriented to mobile network planning. The four phases of a cellular system will be studied: planning, deployment, optimization and maintenance.

Students will develop a planning project for a specific area, considering population, orography and propagation models, estimated heterogeneous traffic and different type of cells: rural to urban, from macro-cells to very small-cells and femto-cells in an Heterogeneous Network configuration.

LTE and LTE-A will be the basis of the project. A detailed description of all those parameters required for the network planning will be given being some of them: pilot signals, power levels and power control, resource block definition and contiguous or discontinuous assignment, frequency reuse facilities, uplink and downlink differences, implementation of carrier aggregation, coexistence of macro and small cells in the same area, detailed parameters and configuration of macro, pico and femto-cells.

Future 5G networks will focus on Self Organizing Networks functionalities (SON) to guarantee that the best configuration is applied on a real time basis. One of the key objectives is the self-configuration and self-optimization of control parameters of Radio Resource Management (RRM) algorithms. Some of them are: Automatic neighbor relations, load balancing, handover optimization including vertical handover, coverage and capacity optimization, inter-cell interference coordination, cell-edge control, traffic behavior and resource block assignment, transmission powers, quality metrics and indicators of switching on-off cells, massive MIMO configuration, antenna tilt and beam-forming, among others.

Dynamic radio configuration is also another key point to be included. Set list of parameters measured at the eNodeB and those reported by the User Equipment. Coordination among different eNodeBs and other network entities through X2 and S1 links allowing self-healing and automatic eNodeB reconfiguration.

All the Radio Resource facilities will be analyzed not only from the point of view of coverage and capacity optimization, but also from the point of view of green network deployment taking into account spectrum and energy efficiency. Energy consumption of the different parts of the network will be included in the analysis considering different states: transmitting, receiving, idle, sleeping, etc. The rules to perform a joint optimization of the network in both capacity and energy efficiency are analyzed and implemented in the project.
Evaluation Criteria:

- Students will have to deliver one or more reports regarding its progress. These project reports will count for 80% the final mark.
- A final exam will account for 20% the final mark.
Applied Image Processing (3 ECTS)

Advanced image and video technologies to design environment recognition applications

- Recent advances in 2D and 3D image capture and representation devices.
- Next generation video coding standards for Ultrahigh-Definition and 3D systems
- Efficient algorithms for image segmentation
- Techniques for representation, description and analysis of color, motion and shape
- Image processing software tools for application oriented design

- Recent advances in 2D and 3D image capture and representation devices
  

- Next generation video coding standards for Ultrahigh-Definition and 3D systems
  

- Efficient algorithms for image segmentation
  

- Techniques for representation, description and analysis of color, motion and shape
  

- Image processing software tools for application oriented design
  
  Commercial software packages for developing image processing and analysis applications. Development of applications in different devices using OpenCV.

Evaluation Criteria:

Reports developed by the student as the result of proposals for ‘Study, implementation and analysis of key algorithms in image processing’: 35%

Final Exam: 65%
Low-power systems with energy harvesting (3 ECTS)

Autonomous sensors nodes based on embedded processors operated from low power supply sources.

- Low-power embedded systems
- Analog front and back ends
- Power Management strategies
- Battery management and energy supervision
- Energy harvesting and power conditioning

- Low-power embedded systems

- Analog front and back ends

- Power management strategies
  Dynamic power management: break-even time and switching policies. Dynamic voltage and frequency scaling: supply voltage and clock frequency optimization.

- Batteries and energy supervision

- Energy harvesting and power conditioning
  DC/DC switching power converters. Photovoltaic energy harvesting: irradiation analysis and system design. Alternative power sources: mechanical, thermal and RF energy harvesting.

Evaluation criteria:

Short test (20 %), laboratory project (60 %), final exam (20 %).
Augmented reality & smart objects (3 ECTS)

The combination of internet and emerging technologies such as augmented reality, real-time localization or embedded sensors lets us transform everyday object into smart objects that can understand and react to their environment, enabling in that way novel computing applications.

- Hardware for augmented reality
- Software and algorithms for augmented reality
- Smart object typology
- Applications

This course will show how augmented reality based on geolocalization technology is used as a channel to represent real time data obtained from embedded sensors in smart objects in a relevant and understandable way. The core of the course is a small project based on Unity3D tool which allows to create multiplatform augmented reality applications that use real time data obtained from the city embedded sensors.

The course assessment is based on two tasks:

1. (50% of the final grade) A guided augmented reality application based on GPS to filter augmented data using Unity3D
2. (50% of the final grade) Integration of real time data from smart objects on the application
Service Engineering (3 ECTS)

Description
Design, dimensioning, operation and management of advanced networked services.

Contents

- **Introduction to networked services**
  - Taxonomy, classification
  - Technical, economy, and human factors
  - Design procedures and reference frameworks
    - Life cycle: pre-selling/engineering, development/pre-production, production/operations.
    - Information Technology Infrastructure Library (ITIL).
    - Enhanced Telecom Operations MAP (eTOM)
  - Key Performance Indicators (KPIs), Service Level Objectives (SLOs), Service Level Agreements (SLAs).
  - Current service architectures

- **Dimensioning of services**
  - Virtualization of resources (servers, networks)
  - Mathematical models for dimensioning
    - Demand analysis and forecast
    - Capacity, load balancing. Optimization of goals (delay, availability, power consumption).

- **Provisioning of services**
  - Automation of procedures.
  - Orchestration of resources. Architectures, protocols, techniques.

- **Operations Management**
  - Monitoring
  - Capacity scaling
  - Performance evaluation
    - Best practices
    - Statistical analysis of results

- **Conclusions, Advanced topics and Future trends.**

Throughout the course, two scenarios will be used as practical cases over which students will apply the concepts learnt.

- Case 1: Data Centres. Topologies, network technologies, virtualization techniques, dimensioning, optimization.
- Case 2: Content Delivery Networks (CDN) for massive-scale distribution of file-based objects or live audiovisual streams. Models, protocols, operations, optimization.

Evaluation Criteria
- 50% Weekly assignments. Students will produce reports based on analysis of real cases.
- 50% Final exam.
Body sensor nodes (3 ECTS)

Design techniques to enable the detection of small body signals in realistic scenarios.

- Physiological and body position and movement sensors
- Low-noise sensor interfaces
- Interference reduction
- Sensor node implementation (Laboratory project)

- Physiological and body position and movement sensors
  

- Low-noise sensor interfaces design
  

- Interference reduction
  

- Sensor node implementation (Laboratory project)
  
  Design, implementation, verification and validation of a system able to measure a physiological or biomechanical parameter: heart rate monitor, apnea detector, photoplethysmography, biofeedback, fall detection.

Evaluation criteria:

Short test (15 %), laboratory work, results and report (35 %), final exam (50 %).
Creativity & Engineering (3 ECTS)

Techniques and tools to enhance and develop creativity as well to facilitate the appreciation of creativity in other people.

- Problem solving and killer applications
- Critical thinking and the role of the mind in learning
- Promoting creativity and team leadership
- Creative techniques

Description:

This subject will facilitate students to understand and practice the techniques and tools that enable them to enhance and develop their creativity as well as the appreciation of creativity in other people. In this subject, students will learn the techniques of problem solving in engineering and the knowledge and use of creative techniques for obtaining new or alternative solutions, to teamwork, to motivation, for improving performance of alternative solutions, as well as the concept of innovation in all areas of their future professional work. Following a methodology based on logic, scientific method, and statistical decision theory, the student will focus problems, to appreciate the importance of the environment and interaction with the systems, and the influence of their knowledge and perception in search for information. When students have successfully completed this course will be able to troubleshoot, optimize and design products and services, dissect arguments, distinguish between good and bad reasoning, fallacies discover and find and target the key elements of a discussion. There will also be encouraged critical thinking, enabling them to articulate and defend their own views and recognize and identify possible defects in their beliefs and reasoning.

1. **Introduction. Some critical concepts. Taxonomies.**
   - Ideas
   - Creativity
   - Engineering problem solving
   - Effectiveness vs. Efficiency
   - Identity Environment-System
   - Innovation
   - Types of Innovations
   - The “killer applications”
   - Keys for a innovative entrepreneurship
   - Innovation cases
   - Reflections about Innovation
   - Inventions
   - Examples and Creativity cases
   - Creativity performance
   - Features of geniuses

2. **Critical Thinking**
   - Data, information and knowledge
   - Critical Thinking
   - Famous engineers performances
   - Development of knowledge
   - Research and obtain information
   - Perception
   - Thinking and reasoning
• Conscious and subconscious Mind.
• Role of the Mind in Learning
• The Heuristics
• Reasoning
• Brain and Mind, role of the cerebral hemispheres

3. Problem Solving and Engineering Design
• Finding creative solutions
• Strategy to promote creativity.
• Convergent and Divergent Problems
• Procedures for obtaining solutions.
• Team Leadership
• Leadership and Executive Intelligence.

4. Creative Techniques

• Pure Creative techniques.
  o Lateral Thinking
  o Reversal Techniques
  o Analogies Method
  o Forced Relationship Techniques
  o Strata
  o Da Vinci Technique
  o Automated Writing Technique
  o Pseudo Dream Technique

• Creative Systematized Techniques
  o Logical Thinking
  o Tree of Ideas or Mind Maps
  o SWOT (Strengths, Weaknesses, Opportunities, and Threats)
  o "Six Hats" Method
  o Discretization, partition or division Techniques.
  o Morphological Matrix Method.
  o Key Questions Technique
  o Brainstorming
  o CPS (creative problem solving)
  o TRIZ method
  o Delphi Method

6. Summary and Conclusions
• Summary of all main subject concepts.
• Critical review of the subject and teacher.
• Proposed improvements

Evaluation Criteria:

• Weekly Exercises (50%)
• Final Assessment Work (50%)
Big Data & Data Mining (6 ECTS)

Ubiquitous information-sensing mobile devices, cameras, microphones, wireless sensor networks, etc., make available today extraordinarily large data sets coming from many areas (science, business, government, etc.). However, how to capture, store, search, share, transfer, analyze and visualize these large data sets in efficient ways?

- Definitions
- Storing big data
- Processing big data
- Tools and techniques to analyze big data
- Automatic recognition of patterns in large data set
- Recommender systems

The course will discuss the idea of big (and open) data and the numerous challenges associated with this concept (storing, processing, analyzing large sets of data in efficient ways). The course will consider data mining techniques and machine learning algorithms as key techniques to address these challenges. The central element of the course will be a small project using two tools: Apache Hadoop and Apache Mahout. Hadoop is a tool for creating parallel algorithms that can process very large amounts of data on distributed architectures. This tool is based on the MapReduce programming model. On the other hand, Mahout is a tool for pattern recognition and recommendation.

The course assessment is based on two guided exercises using Hadoop and Mahout (30% of the final grade) and a small project using both tools (70% of the grade).
Network Security Authentication & Authorization (3 ECTS)

Description
Securing credentials and service data over the network.

Contents
- Security Introduction
- Secure Storage of Credentials
- Passwords/credentials auditing
- User/service authentication
- Authenticated services and credential sharing

- Security Introduction
  An overview of network security basics (CIA, MACs, digital signatures, dynamic key management, et.) and an introduction to virtualization of network scenarios.

- Secure Storage of Credentials
  Securing DBs, password hashing, salted hashes, proper access control, and secure transmission of credentials.

- Passwords/credentials auditing
  The insides of password guessing and main password guessing/auditing tools.

- User/service authentication
  Authentication protocols and access control.

- Authenticated services and credential sharing
  Authentication cookies, credential delegation and credential sharing.

Evaluation Criteria
- Students will have to deliver one or more reports/practical tasks regarding its progress.
- A final exam will count for half the final mark.
Software Defined Radio (3 ECTS)
Design of more versatile, powerful, efficient and portable wireless transceivers

- Cognitive and Software Defined Radio
- Cloud-RAN
- Digital signal generation and processing strategies
- Advanced high-efficient transceiver architectures
- Linear and nonlinear characterization and compensation

- Cognitive and Software Defined Radio
The evolution of wireless systems has followed a long path from the conventional voice-centric cellular systems. The data traffic associated to wireless communications has experienced a high increase thanks to the arrival of multimedia applications. New generation of wireless systems tries to accommodate this increasing demand by means of new transmission technologies and an improved resource management. The improvement in the efficiency of Spectrum use combined with Software Radio and the idea that cognitive learning can be applied to wireless system deployment and management is creating new research and business possibilities. Application of Cognitive Radio and SDR in advanced communications systems constitutes the basis for incorporating learning functions for the management of spectrum and network resources.

- Cloud-RAN
An emerging term in radio access network (RAN) architecture is defined by “Cloud-RAN” concept. The basic idea behind C-RAN is changing the traditional RAN architecture to take advantage of cloud computing, Software-Defined Radio (SDR), Software-Defined Networks (SDN) and Distributed Antenna Systems (DAS). C-RAN is a RAN architecture that is not bound to a single RAN air interface technology. Essentially, conventional cellular base stations are replaced by small remote radio heads connected by optical fiber to a data center where digital processing of physical layer, and the rest of network layers, is carried out. Current cloud computing management frameworks, like OpenStack, OpenNebula, etc, needs to address the intensive real-time computing requirements of modern and future wireless systems. Incorporation of cloud concepts, like resource virtualization, combined with centralized management promises relevant reduction in CAPEX and OPEX and facilitates the incorporation of Coordinated Multi-Point (CoMP) transmission and reception or Inter-cell interference coordination (ICIC).

- Digital signal generation and processing strategies
Current and future wireless communication standards and its related technologies (LTE, LTE-Advanced, WiMAX, etc) are being defined with enough flexibility to allow the inclusion in the processing chain concepts or subsystems aimed at improving the radio communication capabilities. Among others, we can analyze the impact of including within the transceiver signal processing strategies to improve both signal’s integrity and the overall system’s efficiency: crest factor reduction techniques to moderate the signal’s PAPR, dynamic supply or dynamic load modulation strategies to improve the transceiver
efficiency, steerable antennas to perform beamforming, MIMO, or the incorporation of processing components for coordinated transmission (CoMP) or interference mitigation (ICIC), etc.

- Advanced high-efficient transceiver architectures

Using the classical Cartesian I-Q transceivers to cope with non-constant envelope modulated signals with high peak-to-average power ratios (LTE, LTE-Advanced, WiMAX) clearly results power inefficient. To overcome this power efficiency limitation, the conventional Cartesian transceiver architectures are being modified or adapted to ensure optimal system-level amplification with highly efficient switching mode RF PAs. System level architectures (some including power supply control) with great potential for high-efficiency operation such as: linear amplification with nonlinear components (LINC), $\Delta \Sigma$ modulator-based or “all-digital” transmitters, envelope tracking (ET) PAs or polar transmitters (PTs), have been revived thanks to current high-speed digital signal processors (DSP) which substitute their analog counterparts, subjected to tolerances and periodic adjustments.

- Linear and nonlinear characterization and compensation

In the transmitter, linearity levels specified in the communication standards must be meet at the antenna side. One of the most significant sources of nonlinear distortion within the transmitter is the power amplifier. Linearization techniques are therefore aimed at compensating for any eventual linear or nonlinear distortion threatening the transmitter’s linearity specifications. On the other hand, in the receiver side, digital signal processing techniques have to be carried out (e.g. synchronization, channel estimation and equalization) to cope with communication’s channel linear distortion and noise and thus guarantee a certain QoS.

Evaluation Criteria:

- Students will have to develop and make a final presentation of one of the proposed projects.
- A final exam will account for half the final mark.
Project on ICT-based Business Models (3 ECTS)

Applying innovation and entrepreneurship concepts to define a new business model based on ICT.

- Planning activities to develop a new business model
- Project management
- Generation of an innovative idea (students project, first part)
- Activity plan to develop a new business model (students project, second part)
- Selling the project (students project, third part)

- Planning activities to develop a new business model

The course is based in the previous mandatory course “ICT-based entrepreneurship”. The difference between a conventional business plan and the development of a new business model is presented. The elements that should be included in an activity plan to develop a business model are discussed.

- How to manage a project

Topics: Project management philosophy and strategy. Objectives and tools of project management. Teamwork, roles in a team and task assignment. Project charter, status project reports and final project report. Software alternatives to manage a project.

- Generation of an innovative idea (students project, first part)

The students form teams and propose an innovative solution or product related to or using ICT technologies.

- Activity plan to develop of a new business model (students project, second part)

The teams prepare an activity plan to develop a new business model based on the proposed idea. A canvas tool is used.

- Business model

The team prepares in detail and defends the new business model proposed.

Evaluation Criteria:

The assessments will be based on the project developed. The students will be asked to present three partial deliverables, corresponding to the points 3 to 5 showed before. Each partial deliverable will account for 10% of the final note. A final presentation will be performed. The presentation itself will account for 20% of the final assessment while the project itself will count for the other 50%.