الجمهورية الجزائرية الديمقراطية الشعبية
République Algérienne Démocratique et Populaire
وزارة التعليم العالي والبحث العلمي
Ministère de l'Enseignement Supérieur et de la Recherche Scientifique

Université de

logo

Mise à Jour Mai 2025

OFFRE DE FORMATION
INGENIEUR D'ETAT

Parcours ST

Année universitaire :

Établissement	Faculté / Institut	Département

Domaine	Filière	Spécialité
Sciences et Technologies	***Telecommunications***	***Advanced Technologies in Telecommunications***

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اللجنة البيداغوجية الوطنية
لميدان العلوم و التكنولوجيا
Comité Pédagogique National du Domaine Sciences et Technologies

عرض تكوين
مهندسدولة

المؤسسة	الكلية/ المعهد	القسم

الميدان	الفرع	التخصص
علوم وتكنولوجيا	اتصالات سلكية و لا سلكية	التقنيات المتقدمة في الاتصالات

Etablisement :
*Intitulé : **A**dvanced **T**echnologies in **T**elecommunications* *.Année universitaire :*

II – Fiches d'organisation semestrielles des enseignements de la spécialité

Semestre 5 :

Unité d'enseignement	Intitulés des matières	Crédits	Coefficients	Volume Horaire Hebdomadaire			VHS	Mode d'évaluation	
				Cours	TD	TP		Contrôle continu	Examen final
UE Fondamentale Code : UEF 1 Crédits : 12 Coefficients : 7	Digital Signal Processing	**7**	**4**	3h00	1h30	1h30	90h00	40% (20% TD + 20% TP)	60%
	Digital Electronics	**5**	**3**	1h30	1h30	1h30	67h30	40% (20% TD + 20% TP)	60%
UE Fondamentale Code : UEF 2 Crédits : 10 Coefficients : 6	Antennas and Wireless Propagation	**5**	**3**	1h30	1h30	1h30	67h30	40% (20% TD + 20% TP)	60%
	RF Communication Fundamentals	**5**	**3**	1h30	1h30	1h30	67h30	40% (20% TD + 20% TP)	60%
UE Méthodologique Code : UEM 1 Crédits : 6 Coefficients : 4	Object Oriented Programming	**3**	**2**	1h30	-	1h30	45h	40%	60%
	Optimization Techniques and Algorithms	**3**	**2**	1h30	-	1h30	45h	40%	60%
UE Decouverte Code : UED 1 Crédits : 1 Coefficients : 1	Data Science in Telecommunication Industry: use cases	**1**	**1**	1h30	-	-	22h30	-	100%
UE Transversale Code : UET 1 Crédits : 1 Coefficients : 1	English for Engineers	**1**	**1**	1h30	-	-	22h30	-	100%
Volume Horaire Total du Semestre 5		**30**	**19**	**12h00**	**6h00**	**10h30**	**427h30**		

Semestre 6 :

Unité d'enseignement	Intitulés des matières	Crédits	Coefficients	Volume Horaire Hebdomadaire			VHS	Mode d'évaluation	
				Cours	TD	TP		Contrôle continu	Examen final
UE Fondamentale Code : UEF 1 Crédits : 10 Coefficients : 6	Advanced Signal Analysis.	**5**	**3**	1h30	1h30	1h30	67h30	40% (20%TD+ 20%TP)	60%
	Fundamentals of Information Theory and Coding.	**5**	**3**	1h30	1h30	1h30	67h30	40% (20%TD+ 20%TP)	60%
UE Fondamentale Code : UEF 2 Crédits : 10 Coefficients : 6	IP Network and Service Engineering.	**5**	**3**	1h30	1h30	1h30	67h30	40% (20%TD+ 20%TP)	60%
	Optical Networks	**5**	**3**	1h30	1h30	1h30	67h30	40% (20%TD+ 20%TP)	60%
UE Méthodologique Code : UEM 1 Crédits : 9 Coefficients : 6	Administration of Linux Systems	**3**	**2**	1h30	-	1h30	45h00	40%	60%
	Architectures and Programming of Embedded Systems	**3**	**2**	1h30	-	1h30	45h00	40%	60%
	Computer Vision	**2**	**1**	1h30	-	1h30	45h00	40%	60%
	Immersion Internship 1	**1**	**1**	Volumee horaire hors quota (en moyenne 100 heures) Tutorat : 1h30 TP hebdomadaire				100%	-
UE Transversale Code : UET 1 Crédits : 1 Coefficients : 1	Entrepreneurship and Start-up	**1**	**1**	1h30	-	-	22h30	-	100%
Volume Horaire Total du Semestre 6		**30**	**19**	**12h00**	**6h00**	**10h30**	**427h30**		

Semestre 7 :

Unité d'enseignement	Intitulés des matières	Crédits	Coefficients	Volume Horaire Hebdomadaire			VHS	Mode d'évaluation	
				Cours	TD	TP		Contrôle continu	Examen final
UE Fondamentale Code : UEF 1 Crédits : 10 Coefficients : 6	RF Circuits Design	**5**	**3**	1h30	1h30	1h30	67h30	40% (20%TD+ 20%TP)	60%
	Digital Communication Systems	**5**	**3**	1h30	1h30	1h30	67h30	40% (20%TD+ 20%TP)	60%
UE Fondamentale Code : UEF 2 Crédits : 10 Coefficients : 6	Coding and Compression	**5**	**3**	1h30	1h30	1h30	67h30	40% (20% TD + 20% TP)	60%
	Multimedia Transmission	**5**	**3**	1h30	1h30	1h30	67h30	40% (20%TD+ 20%TP)	60%
UE Méthodologique Code : UEM 1 Crédits : 8 Coefficients : 5	Web & Mobile Application Development	**3**	**2**	1h30	-	1h30	45h	40%	60%
	Advanced IP Network and Service Engineering	**3**	**2**	1h30	-	1h30	45h	40%	60%
	Projet Personnel Professionnel	**2**	**1**	Volumee horaire hors quota Tutorat : 1h30 TP hebdomadaire				100%	-
UE Decouverte Code : UED1 Crédits : 1 Coefficients : 1	SatelliteNetworks	**1**	**1**	1h30	-	-	22h30	-	100%
UE Transversale Code : UET 1 Crédits : 1 Coefficients : 1	Mobile Marketing	**1**	**1**	1h30	-	-	22h30	-	100%
Volume Horaire Total du Semestre 7		**30**	**19**	**12h00**	**6h00**	**9h00**	**405h00**		

Etablisement :
Intitulé : Advanced Technologies in Telecommunications *Année universitaire :*

Semestre 8 :

Unité d'enseignement	Intitulés des matières	Crédits	Coefficients	Volume Horaire Hebdomadaire			VHS	Mode d'évaluation	
				Cours	TD	TP		Contrôle continu	Examen final
UE Fondamentale Code : UEF 1 Crédits : 10 Coefficients : 6	Advanced Wireless Communications	**5**	**3**	1h30	1h30	1h30	67h30	40% (20%TD+ 20%TP)	60%
	AI-based Machine Learning	**5**	**3**	1h30	1h30	1h30	67h30	40% (20%TD+ 20%TP)	60%
UE Fondamentale Code : UEF 2 Crédits : 10 Coefficients : 6	Design of Mobile Networks	**5**	**3**	1h30	1h30	1h30	67h30	40% (20% TD + 20% TP)	60%
	IoT Networks	**5**	**3**	1h30	1h30	1h30	67h30	40% (20%TD+ 20%TP)	60%
UE Méthodologique Code : UEM 1 Crédits : 8 Coefficients : 5	SoC FPGA for Embedded Systems	**3**	**2**	1h30	-	1h30	45h00	40%	60%
	SDR-based Design for RadioCom	**3**	**2**	1h30	-	1h30	45h00	40%	60%
	Immersion Internship2	**2**	**1**	Volumee horaire hors quota (en moyenne 100 heures) Tutorat : 1h30 TP hebdomadaire				100%	-
UE Decouverte Code : UED1 Crédits : 1 Coefficients : 1	FieldbusSystems	**1**	**1**	1h30	-	-	22h30	-	100%
UE Transversale Code : UET 1 Crédits : 1 Coefficients : 1	Compliance with Standards and Rules of Ethics and Integrity	**1**	**1**	1h30	-	-	22h30	-	100%
Volume Horaire Total du Semestre 8		**30**	**19**	**12h00**	**6h00**	**9h00**	**405h00**		

Etablisement :
Intitulé : Advanced Technologies in Telecommunications *Année universitaire :*

Semestre 9 :

Unité d'enseignement	Intitulés des matières	Crédits	Coefficients	Volume Horaire Hebdomadaire			VHS	Mode d'évaluation	
				Cours	TD	TP		Contrôle continu	Examen final
UE Fondamentale Code : UEF 1 Crédits : 10 Coefficients : 6	AI-based Deep Learning for Telecommunications	**5**	**3**	1h30		1h30	67h30	40% (20%TD+ 20%TP)	60%
	Wireless Sensor Networks	**5**	**3**	1h30	1h30	1h30	67h30	40% (20%TD+ 20%TP)	60%
UE Fondamentale Code : UEF 2 Crédits : 8 Coefficients : 4	Fundamentals of Networks Security	**4**	**2**	1h30	1h30	1h30	45h	40% (20%TD+ 20%TP)	60%
	Modern Networking	**4**	**2**	1h30		1h30	45h	40%	60%
UE Méthodologique Code : UEM 1 Crédits : 9 Coefficients : 6	Cloud and Edge computing	**3**	**2**	1h30	-	1h30	45h	40%	60%
	Development and Programming of IoT Systems	**3**	**2**	1h30	-	1h30	45h	40%	60%
	Project: IA, IoT, Wireless Com, Security	**3**	**2**	-	-	3h00	45h	100%	-
UE Transversale Code : UET 1 Crédits : 3 Coefficients : 3	Literature Review and Thesis Design	**1**	**1**	1h30	-	-	22h30	-	100%
	Reverse engineering	**2**	**2**	1h30	1h30 atelier		45h	40%	60%
Volume Horaire Total du Semestre 9		**30**	**19**	**12h00**	**3h00**	**13h30**	**427h30**		

Etablisement :
Intitulé : Advanced Technologies in Telecommunications *Année universitaire :*

Semestre 10:

Le stage obligatoirement en relation avec le secteur industriel ou dans une enterprise, estsanctionné par un mémoire et une soutenance

	VHS	Coeff	Crédits
Travail Personnel	**375**	**9**	**15**
Stage en entreprise	**375**	**9**	**15**
Séminaires			
Autre (Encadrement)			
Total Semestre 10	**750**	**18**	**30**

Ce tableau est donné à titre indicatif

Évaluation du Projet de Fin de Cycle d'Ingénieur

- Valeur scientifique (Appréciation du jury) /6
- Rédaction du Mémoire (Appréciation du jury) /4
- Présentation et réponse aux questions (Appréciation du jury) /4
- Appréciation de l'encadreur /3
- Présentation du rapport de stage (Appréciation du jury) /3

Programmes détaillés des matières du 5ème semestre

SEMESTRE	Intitulé de la matière	Coefficient	Crédits
S5	**Digital Signal Processing**	**4**	**7**

VHS	Cours	Travaux Dirigés	Travaux Pratiques
90h30	3h00	1h30	1h30

Prérequis:
Théorie du signal.

Objectifs :
Présenter aux étudiants les techniques de base de la conception et de la mise en œuvre de systèmes de traitement du signal numérique.
• Apprendre les méthodes de base de l'analyse spectrale.
• Apprendre aux étudiants à concevoir des filtres numériques.

Contenu de l'enseignement :

Chapter1: Z-Transform
1.1. Definition of the z-transform
1.2. Z-transform properties
1.3. Z-transform function H(z) -transient and Pole-zero representation
1.4. Inverse z-transform
1.5. Structures for FIR and IIR, Direct Form, Cascaded and parallel form
Chapter 2: FIR and IIR Filter Design
2.1. Design of Linear Phase FIR filters using window function
2..2. Design of linear phase FIR filter by the frequency sampling method,
2..3. FIR filter design using the Remez exchange algorithm
2..4. IIR Filter Design by pole and zeros placement
2..5. IIR filter design by Impulse-invariant method
2..6. IIR filter design by Bilinear Transformation
Chapter 3: Stochastic Processes and Random Signals
3.1. Reminders on Random variables and random vectors
3.2. Statistical moments
3.3. Expectations or Moments of a random function
3.4. Stationary processes, power spectal density
3.5. Ergodism concept
3.6. Examples of stochastic processes (Poisson, Gaussian and Markovian processes)
Chapter 4: Linear filtering of random signals
4.1. Random and SLIT processes
4.2. Optimal filtering
4.3. Adapted filtering
Chapter 5: Random signal modeling
5.1. Autoregressive model
5.2. Moving average model
5.3. ARMA model
5.4 LS Model, Pade, Prony
Chapter 6: Estimation and Detection
6.1. Estimators' properties: Bias, Variance, Efficiency, Cramer Rao bound

6.2. Statistical moments estimation
6.3. Minimum Variance unbiased estimator, example: Wiener
6.4. Maximum likelihood estimator
6.5. Bayesian estimation - Minimum Mean-square error (MMSE) and Maximum a Posteriori (MAP) estimation

Travaux pratiques :

Lab1 :Z-Transform
Lab2 : IIR and FIR Filter Design
Lab3: Random processes (Stationarity and Ergodism)
Lab4: Random signals filtering
Lab5: Random signals modeling
Lab6: Estimation and Detection

Modalités d'évaluation :
Interrogation, devoir surveillé, travaux pratiques, examen final.

Référencesbibliographiques:

- J.G. Proakis and D.G. Manolakis, Digital Signal Processing, Prentice Hall of India. 2009
- A.V. Oppenheim, Discrete-Time Signal Processing, Prentice Hall, 2009.
- S.K. Mitra, Digital Signal Processing, A Computer-based Approach, McGraw Hill, 2008

SEMESTRE	Intitulé de la matière	Coefficient	Crédits

S5	Digital Electronics	3	5

VHS	Cours	Travaux Dirigés	Travaux Pratiques
67h30	1h30	1h30	1h30

Prérequis :
Electronique fondamentale.

Objectifs:
The aim of this course is to provide a comprehensive understanding of digital systems, covering fundamental principles and advanced applications. Students will learn to design and analyze combinational and sequential logic circuits, and apply digital design techniques to real systems. The course will emphasize the development of both theoretical and practical skills essential for design engineers.

Contenu de l'enseignement :

Chapter 1: NumberSystems and digital codes

1.1 Overview of Digital Systems
1.2 Number Systems (Decimal number systems, Binary number systems, octal number systems, hexadecimal number systems)
1.3. Number representation in binary (Signed number representation, Magnitude, 1's complement, 2's complement)
1.4. Number conversions (Binary-to-Decimal, Octal-to-Decimal, Hexadecimal-to-Decimal, Decimal-to-Binary, Decimal-to-Octal, Decimal-to-Hexadecimal, Hexadecimal–Binary and Binary–Hexadecimal Conversions)
1.5. Binary Codes
1.5.1. Binary Coded Decimal (Code description, BCD to Binary conversion, Binary to BCD conversion)
1.5.2. Excess-3 Code
1.5.3. Gray Code (Code description, Gray Code–Binary Conversion, Binary–Gray Code Conversion)

Chapter 2: Boolean Algebra and Logic Gates

2.1 Fundamentals of Boolean Algebra (operations and terminology)
2.2. Arithmetic operations in binary codes (Binary addition and subtraction, BCD addition, Binary multiplication, Binary division
2.2 Basic Logic Gates (OR, AND, NOR, NAND, XOR)
2.3. Boolean Theorems (De Morgan's theorem, Transposition theorem, Redundancy theorem, Duality Theorem, Consensus Theorem).
2.4. Simplification techniques (Sum-of-Products Boolean Expressions, Product-of-Sums Expressions, Expanded Forms of Boolean Expressions, Canonical Form of Boolean Expressions, Σ and Π Nomenclature)
2.5 Karnaugh Map (Construction of a Karnaugh Map, Karnaugh Maps for Multi-Output Function)

Chapter 3: Combinational Logic Design

3.1 Introduction to Combinational Circuits

3.2 Design Procedure and Analysis
3.3 Common Combinational Circuits (Half-Adder, Full Adder, Half-Subtractor, Full Subtractro, Controlled Inverter)
3.4. Encoder, transcoder (definitions, priority encoder, Transcoder BCD/EXESS-3, cascading, applications)
3.5. Multiplexer and demultiplexer (definitions, multiplexers for Parallel-to-Serial Data Conversion, cascading multiplexers circuits, Implementing Boolean Functions with Decoders, Cascading Decoder Circuits, applications)
3.6. Analysis of the datasheet of an integrated decoder circuit, list of decoding integrated circuits.
3.7. Practical Design Examples

Chapter 4: Sequential Logic Design
4.1 Introduction to Sequential Circuits
4.2. Flip-Flops: RS flip-flop, RST flip-flop, D flip-flop, master-slave flip-flop, T flip-flop, JK flip-flop.
4.3. Examples of applications with flip-flops: frequency divider by n, pulse train generator, etc.
4.4. Counters: Definition, classification of counters (Synchronous, regular, irregular, asynchronous, complete and incomplete cycles), Implementation of complete and incomplete synchronous binary counters, Excitation tables of JK, D, and RS flip-flops, Implementation of asynchronous binary modulo (n) counters: complete, incomplete, regular, and irregular, Programmable counters (starting from any state).
4.5. Registers: Definition, classic registers, shift registers, loading and retrieving data in a register (PIPO, PISO, SIPO, SISO), Shifting data in a register, universal register, 74LS194A, available integrated circuits, Applications (classic registers, specific counters, queues)
4.6. Design of Sequential Circuits

Chapter 5: Memory and Programmable Logic
5.1 Memory Types and Organization
5.2 Read-Only Memory (ROM)
and Random-Access Memory (RAM)
5.3 Programmable Logic Devices (PLDs)
5.4 Applications of Memory and Programmable Logic.

<u>Travaux pratiques:</u>

Lab 1: Introduction to Binary Numbers and Digital Logic
Conversion between number systems, basic operations with binary numbers, and simple digital circuits using logic gates.
Lab 2: Simplifying Boolean Expressions and Designing Logic Circuits
Using Boolean algebra to simplify expressions, implementing and testing simplified circuits using logic gates and Karnaugh maps.
Lab 3: Designing and Implementing of an Arithmetic Combinational Circuit:
Designing, simulating, and building combinational circuits such as adders, subtractors circuit for 4-bit binary numbers.
Lab 4: Implementation of Common Combinational Logic Functions
Switching circuits (Multiplexer, Demultiplexer), coding and decoding circuits.
Lab 5: Study and Implementation of a Logical Combinational Circuit

Implementation of a logical function using logic gates (Example: a 7-segment display and/or a 2's complement generator for a 4-bit number and/or a Gray code generator for 4 bits, etc)

Lab6: Working with Flip-Flops and Sequential Circuits

Exploring different types of flip-flops, designing and implementing counters and registers, and analyzing the behavior of sequential circuits.

Modalités d'évaluation :

Interrogation, devoir surveillé, travaux pratiques, examen final.

Références bibliographiques :

- *Stephen Brown and Zvonko Vranesic, Fundamentals of Digital Logic with VHDL Design, 4th Edition, McGraw-Hill, 2023.*
- *Donzellini, Giuliano, et al. Introduction to digital systems design. Cham: Springer, 2019.*
- *Widmer, Neal S., Gregory L. Moss, and Ronald J. Tocci. Digital systems: Principles and applications. Pearson, 2018.*
- *Deschamps, Jean-Pierre, Elena Valderrama, and LluísTerés. Digital systems: From logic gates to processors. Springer International Publishing, 2017.*

SEMESTRE	Intitulé de la matière	Coefficient	Crédits
S5	**Antennas and Wireless Propagation**	**3**	**5**

VHS	Cours	Travaux Dirigés	Travaux Pratiques
67h30	1h30	1h30	1h30

Prérequis:

Knowledge of electromagnetism, electronics and Mathematics functions (Derivation, Integration, Trigonometry, Vector Analysis),

Objectifs:

Introduction to electromagnetic radiation in free space, Characterization of an antenna (radiation pattern, gain, directivity, tuning frequency, etc.).

Contenu de l'enseignement :

Chapter 1. Fundamental notions of EM wave propagation

1.1 Electromagnetic radiation
1.2 Maxwell'sequation and waveequation
1.3 Propagation equation in inhomogeneousenvironments
1.4 Reflection/transmission between two LHI environments

Chapter 2. Dipole antennas

2.1 Parameters of an antenna
2.2 Radiation from the Hertz antenna
2.3 Dipole antenna isolated in space
2.4 Effect of ground

Chapter 3. Antenna networks

3.1 Transverse emission antenna networks
3.2 Longitudinal emission antenna networks
3.3 Antenna curtains
3.4 Out-of-phase antenna arrays

Chapter 4 Antennas with radiating surfaces

4.1 Study of radiating surfaces,
4.2 Field distribution,
4.3 Cornet Antennas
4.4 Parabolic antenna

Chapter 5 Planar Antennas

5.1 Patch antennas
5.2 Planar dipoles with CPS or CPW lines
5.3 Planar antenna arrays
5.4 Broadband planar antennas

Chapitre 6. Antennas for Mobile Systems

6.1 Mobile Antenna Systems
6.2 Bases stations
6.3 Different Types of Antennas used in mobile

6.4 Numerical modeling of antenna radiation

Travaux pratiques:

Lab1: Study and measurement of the radiation pattern of a 2GHz dipole antenna
Lab 2: Horn and Pach antennas diagrams
Lab 3: Network antennas (Yagi, Pach)
Lab 4: Connection report with horn antennas

Modalités d'évaluation :
Interrogation, devoir surveillé, travaux pratiques, examen final.

Référencesbibliographiques:

1. *Graf, Rudolf F., ed. (1999). "Antenna".* Modern Dictionary of Electronics. *Newnes.*
2. Elliott, Robert S. (1981). Antenna Theory and Design (1st ed.). Wyle.
3. Smith, Carl (1969). Standard Broadcast Antenna Systems. Cleveland, Ohio: Smith Electronics.
4. Raines, Jeremy Keith (2007). Folded Unipole Antennas: Theory and applications. Electronic Engineering (1st ed.). McGraw Hill.
5. *Stutzman, Warren L.; Thiele, Gary A. (2012).* Antenna Theory and Design *(3rd ed.). John Wiley& Sons.*
6. Monopole Antennas*, p. 340, at Google Books*

SEMESTRE	Intitulé de la matière	Coefficient	Crédits
S5	**RF Communication Fundamentals**	**3**	**5**

VHS	Cours	Travaux Dirigés	Travaux Pratiques
67h30	1h30	1h30	1h30

Prérequis :
Electronique fondamentale, Théorie du signal, Ondes et vibrations.

Objectifs :
Ce cours vise à doter les étudiants d'une solide compréhension des éléments constitutifs des systèmes de télécommunication, incluant les circuits de base, les principes des modulation et démodulation analogiques d'amplitude et de phase. Les étudiants seront également initiés aux architectures des émetteurs et récepteurs RF.

Contenu de l'enseignement :

Chapter1: Introduction to Telecommunications

1.1 Definitions, history, and evolution of telecommunications.
1.2 Concepts of a signal: definition, temporal expression, periodic signal, random signal, analog signal, digital signal, noise, signal power, signal spectrum, bandwidth.
1.3 Elements of a telecommunication chain: the transmitter, the receiver, the transmission channel.
1.4 Frequency bands.

Chapter 2: Basic Circuits for Telecommunication Systems

2.1 Filters
2.2 Amplifiers
2.3 RF Oscillators, VCO
2.4 Mixers
2.5 The PLL

Chapter 3: Amplitude Modulations

3.1 The necessity of modulation
3.2 Amplitude modulation: temporal and frequency study, power.
3.3 DSB modulation, SSB modulation.
3.4 Study of the basic circuits/principles of AM modulation/demodulation.

Chapter 4: Angular Modulations

4.1 Frequency/phase modulation: temporal and frequency study.
4.2 Study of the basic circuits/principles of FM and PM modulation/demodulation.

Chapter 5 : Noise in Telecommunications

5.1 Definition and sources of noise
5.2 Additive White Gaussian Noise (AWGN)
5.3 Thermal noise, equivalent noise temperature, noise figure.
5.4 Signal-to-noise ratio.
5.5 Performance evaluation of modulations (AM/FM) in the presence of noise.

Chapter 6: RF Transmitter and Receiver Architectures

6.1 Operating principle of a radio frequency transmitter
6.2 Receiver performance: noise floor, minimum signal detected by a receiver, sensitivity, stability, selectivity.
6.3 Direct demodulation receiver
6.4 Frequency conversion receiver
6.5 Direct conversion (homodyne) receiver

Travaux pratiques:

Lab 1: Filtering (1st / 2nd order filter).
Lab 2: Oscillator and VCO.
Lab 3: AM modulation/demodulation.

Lab 4: FM modulation/demodulation.
Lab 5: The receiver.

Modalités d'évaluation :
Interrogation, devoir surveillé, travaux pratiques, examen final.

Référencesbibliographiques:

- *Principles of Electronic Communication Systems, Fourth Edition; Louis E. Frenzel Jr ; McGraw-Hill Education, 2016.*
- *Digital and analog communication systems, Eighth Edition; Leon W. Couch II; Pearson Education, Inc, 2013.*
- *Fundamentals of Communications Systems; Michael P. Fitz; McGraw-Hill, 2017.*
- *Communication systems engineering, 2nd Ed. ; John G. Proakis, Masoud Salehi ; Prentice-Hall, Inc. 2002.*
- *Radio-frequency and microwave communication circuits, Analysis and Design, 2e edition; Devendra K. Misra; John Wiley & Sons, Inc, 2004.*
- *Introduction to Wireless Communication Circuits; F. Farzaneh, A. Fotowat, M. Kamarei A. Nikoofard and M. Elmi; River Publishers 2018;*
- *Radio-Frequency Electronics Circuits and Applications 2nd ed; Jon B. Hagen, Cambridge University Press, 2009.*

SEMESTRE	Intitulé de la matière	Coefficient	Crédits
S5	**Object Oriented Programming**	**2**	**3**

VHS	Cours	Travaux Dirigés	Travaux Pratiques
45h00	1h30	-	1h30

Prérequis :
Algorithm design, Python programming.

Objectifs:
In this course, the student will learn the basics of object-oriented programming as well as fundamentals of advanced program design techniques in Python Language.

Contenu de l'enseignement :

Chapter1 : Introduction to object-oriented programming

1.1. What is object-oriented programming (OOP)?
1.2. Class and object definition
1.3. Advantages of OOP (program reuse, abstraction, and encapsulation).
1.4. Module and package creation and importing.

Chapter 2 : Class and Object

2.1. Class creation and instantiation
2.2. Coding and customizing constructor
2.3. Object initialization and attributes (Self and more arguments)
2.4. Object attributes versus class attributes
2.5. Class private attributes
2.5. Object namespace
2.6. Adding behavior methods
2.7. Class with default behavior
2.8. Special class methods (new, getters, setters)
2.9. Generate Multiple instance objects
2.10. Class as attributes in modules and packages
2.11. Coding class trees
2.12. Static methods
2.13. Class composition (Object as other object attribute)
2.14. Object as argument (association of classes)
2.15. Customizing behavior by sub-classing
2.16. Classes versus dictionaries
2.17. Class with nested scope

Chapter 3 : Inheritance and polymorphism

3.1. Object composition and aggregation
3.2. Definition of class inheritance
3.3. Classes are customized by inheritance
3.3. Superclass and derived class
3.4. Private, protected, and pseudo-private class attributes
3.5. Constructor chaining
3.6. Call method from the superclass
3.7. Specializing inherited methods (redefinition, overloading and overriding
3.8. Abstract super-classes
3.9. Extending types by embedding and by sub-classing
3.10. Polymorphism
3.11. The descriptor protocol
3.12. Multiple class inheritance
3.13. Hierarchical class inheritance

Chapter 4 : Advanced OOP : Design patterns

4.1.Introduction to elements of reusable object-oriented software
4.2.Types of design patterns
4.3.Structural patterns

4.4.Function decorators
4.5.Methods decorator (methods without parameters, methods with parameters)
4.6.Decorator nesting (stacked decorators)
4.7.Adding decorator arguments,
4.8.Creational patterns : Abstract Factory, Builder, Prototype, Singleton
4.9.Creating class singleton using function decorator
4.10. Creating singleton using class inheritance
4.11. Adapter pattern

Chapter 5 :Iterables, iterators, generators, co-routines , containers
5.1. Introduction to behavioral patterns
5.2.Observer pattern
5.3.Template pattern
5.4.Iterables
5.5. Iterators
5.6.Iteration related methods
5.7.Intercools module
5.8.generator function
5.9.Nesting generator functions
5.10. Co-routines
5.11. Containers and collection modules
5.12. Queues and stacks
5.13. Higher order functions : Map, Filter and Reduce

Travaux pratiques:

- **Lab1**: Modules and packages creation and manipulation in Python
- **Lab2**: Class and Object manipulation
- **Lab3**: Inheritance and polymorphism
- **Lab4**: Decorators, Singletons , observer and template patterns
- **Lab5**: Iterators and generators (itertool, Pickle, Socket, Urllib2, ftplib, etc)
- **Lab6**: Higher order functions : Map, Filter and Reduce

Modalités d'évaluation :
Interrogation, devoir surveillé, travaux pratiques, examen final.

Référencesbibliographiques:

1. *Anaconda : Anaconda Environments (AEN 4.0) — Anaconda documentation*
2. *J.Chan, 2014. Learn python in one day and learn it well, Edition Eyrolles.*
3. *J. Hunt, 2020. A beginners guide for python 3 programming, Edition Springer*
4. *M. Lutz., 2009. Learning python : Powerful object-oriented programming, Learning Python (ehu.es)*
5. *D. Phillips, 2015. Python 3 object oriented programming, 2ème edition, PACKT publishing, livre.pdf*
6. *H. P. Langtangen, 2014. A primer on scientific programming with python, Springer.*

SEMESTRE	Intitulé de la matière	Coefficient	Crédits
S5	**Optimization Techniques and Algorithms**	**2**	**3**

VHS	Cours	Travaux Dirigés	Travaux Pratiques
45h00	1h30	-	1h30

Prérequis :
Mathématiques Appliquées, Méthodes numériques.

Objectifs :
Ce cours a pour objectif d'initier les étudiants aux concepts fondamentaux et aux méthodes avancées d'optimisation, en mettant un accent particulier sur les problèmes d'optimisation convexe, linéaire, quadratique, et semi-définie positive. À travers des applications pratiques, notamment dans le domaine des télécommunications, les étudiants apprendront à résoudre des problèmes d'optimisation sous contraints et sans contraints, en utilisant des méthodes numériques telles que les méthodes de descente, de gradient, et Newton. Ce cours vise à doter les étudiants des compétences nécessaires pour concevoir des solutions optimales à des problèmes complexes rencontrés dans l'ingénierie et la recherche.

Contenu de l'enseignement :

Chapter 1 : Convex optimization Problems Introduction and Fundamentals

1.1 Basic Convex Optimization Concepts: convex sets, convex functions, …
1.2 Convex Optimization Problems
1.3 Linear Programing Problems

1.4 Quadratic Programing Problems: QCQP, SOCP
1.5 Semi-Definite Programming.
1.6 Application Examples

Chapter 2: Unconstrained Optimization
2.1 General Problem and Existence of Solutions
2.2 Unidimensional Optimization
2.3 Numerical Methods for Optimization of Differentiable Functions: descent methods
2.4 Gradient-Type Methods
2.5 Newton and Quasi-Newton Methods
2.6 Application Examples

Chapter 3: Constrained Optimization
3.1 Equality Constraints and the Method of Lagrange Multipliers.
3.2 Inequality Constraints and Karush-Kuhn-Tucker Conditions.
3.3 Convex Optimization with Constraints.
3.4 Barrier Methods.
3.5 Projected Gradient Methods.
3.6 Application examples

Chapter 4: Multi-Objective Optimization
4.1 Introduction to Multi-Objective Optimization
4.2 Pareto Optimality
4.3 Scalarization Techniques
4.4 Evolutionary Algorithms for Multi-Objective Optimization
4.5 Goal Programming
4.6 Multi-Objective Optimization in Practice
4.7 Application Examples

Travaux pratiques:

Lab 1: SolvingConvexOptimization Problems
- To provide hands-on experience with convex optimization problems using tools like MATLAB or Python (with libraries like CVXPY).
- Activities:
  - Formulating and solving a basic linear programming problem.
  - Implementing and solving a quadratic programming problem.
  - Exploring application examples such as portfolio optimization.

Lab 2: UnconstrainedOptimizationTechniques
- To understand and apply numerical methods for unconstrained optimization.
- Activities:
  - Implementing and comparing unidimensional optimization methods.
  - Using gradient descent and Newton's methods to optimize differentiable functions.
  - Analyzing convergence rates and performance on various test functions.

Lab 3: Constrained Optimization with Equality and Inequality Constraints
- To apply methods for solving constrained optimization problems.
- Activities:

- Solving optimization problems using Lagrange multipliers.
- Implementing the Karush-Kuhn-Tucker conditions for inequality constraints.
- Applying barrier methods and projected gradient methods to real-world problems.

Lab 4: Multi-ObjectiveOptimizationTechniques

- To explore and apply multi-objective optimization methods.
- Activities:
  - Understanding and visualizing Pareto fronts.
  - Implementing scalarization techniques to solve multi-objective problems.
  - Applying goal programming to a practical problem, such as resource allocation.

Lab 5: Real-World Telecommunication Optimization Project

- To integrate and apply all learned techniques to a comprehensive project in telecommunications.
- Activities:
  - Selecting a real-world optimization problem (e.g., logistics, network design, resource allocation).
  - Formulating the problem, identifying constraints, and choosing appropriate optimization techniques.
  - Implementing and solving the problem using a combination of deterministic methods.
  - Presenting the solution approach, results, and analysis in a detailed report.

Modalités d'évaluation :

Interrogation, devoir surveillé, travaux pratiques, examen final.

Référencesbibliographiques:

- *Boyd, Stephen P., and Lieven Vandenberghe, "Convex optimization ", Cambridge university press, 2004.*
- *Saengudomlert, Poompat, "Optimization for communications and networks", CRC Press, 2011.*
- *Nocedal, Jorge, and Stephen J. Wright, eds, "Numerical optimization", New York, NY: Springer New York, 1999.*
- *Nesterov, Yurii, "Lectures on convex optimization", Springer, 2018.*
- *Gui, Guan, and Bin Lyu, "Optimization for Wireless Powered Communication Networks", Springer International Publishing, 2019.*
- *Bruno Clerckx, "Lectures on Convex Optimization for Wirless Communications", Imperial College London, 2024.*

SEMESTRE	Intitulé de la matière	Coefficient	Crédits
S5	Data Science in Telecommunication Industry: Use Cases	1	1

VHS	Cours	Travaux Dirigés	Travaux Pratiques
22h30	1h30	-	-

Prérequis :
Programmation, analyse de données, statistique.

Objectifs :
Initier l'étudiant au domaine de la science des données (data science) en explorant les types de données et le rôle des data scientists dans les télécommunications. Des exemples pratiques qui utilisent la science des données dans l'industrie des télécommunications seront discutés. Enfin, les compétences nécessaires pour devenir un data scientist en télécommunications seront présentées.

Contenu de l'enseignement :

Chapitre 1 : Introduction to Data Science

1.1 Whatis data science?
1.2 Where and why is data science needed?
1.3 How Does a Data Scientist Work?
1.4 Tools for Data Science
1.5 Data science methodology
1.6 Databases and SQL for data science with Python (Acquisition of data from various sources, Data processing and analysis for solving problems in various application domains, Data visualization using programming tools, Use of computing infrastructure for efficient data analysis).

Chapitre2 : Introduction to the Telecommunications Industry

2.1 Overview of the telecommunications industry
2.2 Modern telecommunications tools
2.3 Telecommunications equipment & services sector
2.4 Types of data in the telecommunications Industry
2.5 What is the role of a data scientist in telecommunications?

Chapitre3 :Use Cases of Data Science in Telecommunications Industry

3.1 Fraud detection
3.2 Price optimization
3.3 Network optimization
3.4 Real-time analytics
3.5 Preventing Customer Churn
3.6 Targeted marketing
3.7 Network security
3.8 Predective analytics

Chapitre4 :How to Become a Data Scientist in Telecommunications Industry

4.1 Domain knowledge
4.2 Technical skills
4.3 Data Science Career Track

- ✓ Data Warehouse and Business Intelligence
- ✓ Data Science and Advanced Machine Learning
- ✓ Marketing Basics

Modalités d'évaluation :

Interrogation, examen final.

Références bibliographiques :

- *Abdulova Aygun, Hajiyev Huseyn (2022). The implementation of Data Science in telecommunication companies and how it affects problem-solution. Proceedings of the 1st International Scientific and Practical Conference «Science: Development and Factors its Influence» (December 26-28, 2022). Amsterdam, Netherlands*
- *Manvender Singh (2022). Global Certificate in Data Science & AI. 10 Months | Online Instructor Led. Accredian credentials that matter (2022), India.*
- *Hassan Keshavarz, Akbariah Mohd Mahdzir, Hosna Talebian, Neda Jalaliyoon, Naoki Ohshima (2021). The Value of Big Data Analytics Pillars in Telecommunication Industry. Sustainability 2021, 13, 7160.* https://doi.org/10.3390/su13137160
- *Artificial Intelligence (AI) and Big Data for Telecom. FN Division, TEC K.L. Bhawan, Janpath, New Delhi-01, March 2019.*
- https://tec.gov.in/pdf/Studypaper/Study%20Paper%20AI%20and%20Big%20Data%20for%20Telecom.pdf
- *Fauzy Che Yayah, Khairil Imran Ghauth, Choo-Yee Ting (2017). Adopting Big Data Analytics Strategy in Telecommunication Industry. Journal of Computer Science & Computational Mathematics, Volume 7, Issue 3, September 2017.* DOI: 10.20967/jcscm.2017.03.002
- *Sajjad Rehman, Dhary Al-Raqom (2020). Using big data in telecommunication companies: A case study. African Journal of Business Management, Vol. 14(7), pp. 209-216, July, 2020*
- DOI: 10.5897/AJBM2019.8874

SEMESTRE	Intitulé de la matière	Coefficient	Crédits
S5	**English for Engineers**	**1**	**1**

VHS	Cours	Travaux Dirigés	Travaux Pratiques
22h30	1h30	-	-

Prérequis :
Basic knowledge of English.

Objectifs :

Develop skills to read and comprehend scientific papers and technical books.

- Master technical English relevant to engineering fields.
- Learn to write and publish scientific papers.
- Enhance ability to present scientific and technical work effectively.

Contenu de l'enseignement :

Chapter1:Syntax and Semantics in English

- Analysis of scientifictexts
- Examination of texts related to telecommunications
- Review of essential syntax and grammar rules

Chapter2:Idiomatic Expressions in English

- Common English idiomatic expressions
- Specific expressions: proverbs, metaphors, and anaphora
- Etymological and semiological analysis of English expressions

Chapter3:Technical English in Telecommunications

- Introduction to technical terminology in telecommunications
- Detailed examination and interpretation of technical texts
- Practical exercises in using telecommunications terminology

Chapter 4: Study and Analysis of Scientific Papers

- Introduction to scientific papers: structure and purpose
- Techniques for comprehending and analyzing scientific and technical papers
- Reviewing and discussing technical documentaries related to telecommunications
- Exercises in listening and technical English communication

Modalités d'évaluation :

Interrogation, examen final.

Références bibliographiques :

Handouts distributed in class.

Programmes détaillés des matières du 6ème semestre

SEMESTRE	Intitulé de la matière	Coefficient	Crédits
S6	**Advanced Signal Analysis**	**3**	**5**

VHS	Cours	Travaux Dirigés	Travaux Pratiques
67h30	1h30	1h30	1h30

Prérequis :
Théorie du signal, Digital Signal Processing.

Objectifs :
Appliquer les concepts et méthodes fondamentaux de probabilité pour développer des compétences en résolution de problèmes. Construire les bases théoriques des étudiants dans les domaines de la communication, du traitement des signaux réels et des réseaux.

Contenu de l'enseignement :

Chapter 1 : Multirateprocessing
1.1. Down-sampling and up-sampling
1.2. Polyphases decomposition
1.3. Multistage Multirate LPF
1.3. Sample rate conversion
1.4. M-Channel Filter banks
1.5. Two channel perfection reconstruction filterbanks
1.6. Combs Filter
1.7. Application of Multirate DSP – Delta Sigma A/D conversion
Chapter 2: Time-frequency analysis
2.1. Short time Fourier transform
2.2. Wigner-Ville transform
2.3. Continuous Wavelet transform
2.4. Discrete Wavelet transform
Chapter 3: Adaptive Filtering
3.1. Optimum Filtering
3.2. Gradient-based adaptive filters (Steepest descent, LMS)
3.3. Recursive Least Square
3.4. Adaptive IIR Filters
3.5. Discrete Kalman and Particles Filters
Chapter 4: Digital Filter Implementation
4.1. Implementations using special purpose DSP processors,
4.2. Bit-serial arithmetic, pipelined implementations,
4.3. Distributed arithmeticimplementations.

Travaux pratiques :

Lab1: Down-sampling and up-sampling
Lab2: M-Channel Filter banks
Lab3: Delta Sigma A/D conversion
Lab4: Time-frequency analysis
Lab5: Discrete wavelet applications
Lab6: Adaptive Filtering

Modalités d'évaluation :
Interrogation, devoir surveillé, travaux pratiques, examen final.

Référencesbibliographiques:

-D. P. Bertsekas, J. Tsitsiklis, "Introduction to Probability", Athena Scientific, 2nd Edition, 2008.

- M. Carlton and J. Devore, "Probability with Applications in Engineering, Science and Technology", Springer, 2nd Edition, 2017.
- Leon-Garcia, "Probability and Random Processes for EE", Addison Wesley, 2nd Edition, 1994.
- M. H. Hayes, Statistical Signal Processing and Modeling, Wiley, New York, NY, 1996.
- C. W. Therrien, Discrete random signals and statistical signal processing, Prentice Hall, c1992.
- A. Papoulis, Probability, Random Variables, and Stochastic Processes, 3rd edition, McGraw Hill, 1991.
- S. M. Ross, Introduction to probability models, 7th ed. Harcourt Academic Press, 2000.

SEMESTRE	Intitulé de la matière	Coefficient	Crédits
S6	**Fundamentals of Information Theory and Coding**	**3**	**5**

VHS	Cours	Travaux Dirigés	Travaux Pratiques
67h30	1h30	1h30	1h30

Prérequis:
Probability and statistics.

Objectifs:
Familiarize the student with information theory and data coding techniques such as channel coding and source coding. From this material, the student will have to learn the basic foundations for illustrating the importance and impact of information theory and coding in everyday life. For instance, discuss how information theory influences the design of communication systems, data compression algorithms, and error-correcting codes used in digital communication and storage.

Contenu de l'enseignement :

Chapter 1 : Information measure and transmission system

1.1 Terminology
1.2 Role of an ITT (Information Transmission System)
1.3 Model of an ITS
1.4 Memoryless Information Sources
1.5 Measure of Discrete Information
1.6 Information Entropy for a DMS (Shannon Entropy)
1.7 Source Redundancy and Efficiency
1.8 Moments and Moment Rate
1.9 Information Rate, Decision Rate
1.10 Discrete Transmission Channels (Probabilities and Entropies in Discrete Channels, Mutual Information and Trans-information, Relationshipsbetween Entropies).

Chapter 2 : Discrete source coding

2.1 Aim of Source Coding
2.2 Information Representation Codes
2.3 Coding Efficiency: Compression Ratio
2.4 Existence Theorem for Instantaneous and Uniquely Decodable Codes (Kraft and McMillan Inequalities)
2.5 Shannon First Theorem (1948)
2.6 Losseless Compression Algorithms (Shannon-Fano Binary Coding, Huffman Algorithms, Run Length Coding (RLC), Arithmetic Coding, Lempel Ziv Coding, Lempel-Ziv-Welch Coding).

Chapter 3 : Discrete communication channels

3.1 DiscreteMemorylesschannel
3.2 Channel transition matrix
3.3 Symmetricchannel
3.4 Channel capacity
3.5 Channel models (Noiseless Channel, Binary Symmetric Channel (BSC), Binary Erasure Channel (BEC), Z-Channel, Additive White Gaussian Noise Channel, Network Channel).

Chapitre4 : Introduction to channel coding

4.1 Shannon Second Theorem (Noisy Channels Coding Theorem)

4.2 Error Control Strategy
4.3 Classification of Error Control Codes
4.4 Representation of Binary Code Sequences
4.5 Parameters of Detecting and Error Correcting Codes
4.6 Maximum LikelihoodDecoding (MLD)
4.7 Linear Block Codes
- 4.7.1 Linear Block Codes : Definition and Matrix Description
- 4.7.2 Error Syndrome
- 4.7.3 Dimensioning of Error Correcting Linear Block Codes
- 4.7.4 Perfect and almost Perfect Codes
- 4.7.5 Detection and Correction Capacity: Decoded BER
- 4.7.6 Relations between the Columns of H Matrix for Error Detection and Correction
- 4.7.7 Standard Array and Syndrome Decoding
- 4.7.8 Comparison between Linear Error Detecting and Correcting Block Codes
- 4.7.9 Hamming Group Codes

Travaux pratiques :

Lab1 : Information measurement (Entropy calculation, mutual information)
Lab2 : Shannon-Fano, Huffman coding
Lab3: Arithmetic Coding
Lab4 LZW coding
Lab5: Transmission in noisy channels
Lab6 : Linear block codes

Modalités d'évaluation :
Interrogation, devoir surveillé, travaux pratiques, examen final.

Référencesbibliographiques:

1. *Borda, M.: Information Theory and Coding. U.T. Pres, Cluj-Napoca (2007).*
2. *Haykin, S.: Communication Systems, 4th edn. John Wiley& Sons, Chichester (2001)*
3. *K. Sayood, "Introduction to Data Compression, Third Edition", Elsevier Inc. 2006.*
4. *Wade, G.: Coding Techniques: An Introduction to Compression and Error Control. Palgrave Macmillan, Basingstoke (2000)*

SEMESTRE	Intitulé de la matière	Coefficient	Crédits
S6	**IP Network and Service Engineering**	**3**	**5**

VHS	Cours	Travaux Dirigés	Travaux Pratiques

67h30	1h30	1h30	1h30

Prérequis:

- Compréhension des concepts fondamentaux de la programmation
- Connaissance des concepts fondamentaux des systèmes d'exploitation/

Objectifs:

- Acquérir une compréhension des technologies et protocoles IP.
- Maîtriser les techniques de conception et de déploiement de réseaux et services IP.
- Être capable d'analyser et de résoudre les problèmes rencontrés dans les réseaux IP.

Contenu de l'enseignement :

Chapter 1: TCP/IP Model and IP Addressing Fundamentals

1.1 Overview of IP Networks: Definition and purpose of IP networks. Types of networks (LAN, WAN, MAN). Brief history of the Internet
1.2 The TCP/IP Model : Layers of the TCP/IP model. Functions of each layer. Comparison with OSI model
1.3 Basic Network Devices : Routers. Switches. Hubs and repeaters. Firewalls
1.4 IP Addressing : IPv4 structure. IPv6 basics. Public vs. Private IP addresses
1.5 Subnetting : Subnet masks. CIDR notation. Subnetting practice
1.6 IP Address Management: DHCP basics. Static vs. Dynamic IP addressing. IP address planning

Chapter 2: IP Technologies and Protocols

2.1 TCP/IP Protocols: Focus on essential TCP/IP protocols like TCP, UDP, DNS, DHCP, FTP, HTTP and their functions.
2.2 Ethernet: Detailed explanation of Ethernet, its physical layer, media access control (MAC) addressing, and its role in LANs.
2.3 Wi-Fi: Coverage of Wi-Fi standards (802.11a/b/g/n/ac), wireless security protocols (WPA/WPA2/WPA3), and Wi-Fi network deployment considerations.

Chapter 3: Routing and Switching Fundamentals

3.1 IP Routing:
- Fundamentals of routing
- Routingtables: structure and function
- Static routing: configuration and use cases
- Dynamic routing:principles and advantages
- Routing protocols : RIP, OSPF, RIPng.

3.2 Switching:
- Function, switching decisions, basic configuration
- Types of switches: Managed vs. Unmanaged, Layer 2 vs. Layer 3 switches
- Virtual LANs (VLANs) and VLAN trunking
- Spanning Tree Protocol (STP) and its variations (RSTP, MSTP)

- Link Aggregation (IEEE 802.3ad)

Chapter 4: IP Network Design and Deployment

4.1 Network Topologies: Detailed analysis of common network topologies (bus, star, ring, mesh), their advantages, and disadvantages.
4.2 Network Design Principles: Principles of designing secure and scalable networks, incorporating redundancy, fault tolerance, and load balancing.
4.3 Network Deployment: Practical guidance on network deployment, configuring network devices, and testing network connectivity.
4.4 Network Troubleshooting: Introduction to basic network troubleshooting techniques, common network problems, and tools like ping, traceroute, and network management tools.
4.5 Network Management: Overview of network management principles, SNMP, network monitoring tools, and log analysis.
4.6 Network Documentation: Emphasis on the importance of network documentation, best practices, and documenting network configuration.

Chapter 5: IP Network Security

5.1 Introduction to Network Security: Basic concepts of network security, firewalls, access control lists (ACLs), and common security threats.
5.2 Firewalls: Detailed coverage of firewalls, firewall types (packet filtering, stateful inspection), and configuring firewall rules.
5.3 VPNs: Introduction to VPNs, their purpose, VPN types (PPTP, L2TP/IPsec, OpenVPN), and configuring basic VPNs.
5.4 Network Security Best Practices: Best practices for securing IP networks, implementing security policies, and managing vulnerabilities.

Travaux pratiques:

Lab 1: Configuring basic IP network infrastructure (routers, switches) using a network simulator (e.g., Cisco Packet Tracer, GNS3). Set up VLANs on a switch. Configure static routes on a router.
Lab 2: Use network exploration tools (e.g., Wireshark) to capture and analyze network traffic. Identify different types of network packets and their components. Analyze different protocols (TCP, UDP, HTTP, DNS). Set up a basic web server and analyze the HTTP traffic. Perform DNS lookups and analyze the results.
Lab 3: Configuring and troubleshooting Wi-Fi network security using Wireshark.
Lab 4: Configuring and analyzing static and dynamic routing protocols (RIP, OSPF).
Lab 5: Implementing basic network security (firewalls, ACLs) using Cisco Packet Tracer or GNS3.
Lab 6: Deploying and testing a simple VPN connection using OpenVPN.

Modalités d'évaluation :
Interrogation, devoir surveillé, travaux pratiques, examen final.

Référencesbibliographiques:

- *Kurose, J. F., & Ross, K. W. (2023). Computer Networking: A Top-Down Approach (9th ed.). Pearson.*

- *Perlman, R. (2021). Interconnections: Bridges, Routers, Switches, and Internetworking Protocols (4th ed.). Addison-Wesley.*
- *Fortz, B., & Le Boudec, J. Y. (2023). Networking: A Comprehensive Approach (4th ed.). Wiley.*

SEMESTRE	Intitulé de la matière	Coefficient	Crédits
S6	**Optical Networks**	**3**	**5**

VHS	Cours	Travaux Dirigés	Travaux Pratiques
67h30	1h30	1h30	1h30

Prérequis:

A background in optoelectronics, electromagnetism, and an understanding of coding and modulation concepts are advantageous for effectively approaching the optical networks module in telecommunications engineering.

Objectifs:

This module aims to train students to design optimal optical network architectures, intelligently manage these networks, and optimize their performance by selecting suitable optical components. These architectures will be applicable to advanced telecommunications, including 5G and potentially 6G technologies.

Contenu de l'enseignement :

Chapter1 : Introduction to Optical Communications

- Definition and role of optical communications in modern networks.
- Contextualization of the importance of optical networks in telecommunications.
- Operating principles of light sources and detectors used in optical networks

Chapter 2: Fundamental Concepts of Optical Transmission

- Principles of light propagation in optical fibers (Snell's law, total internal reflection, propagation modes).
- Fundamental characteristics of optical fibers: Attenuation, Dispersion, Nonlinear Effects
- Special optical fibers (dispersion compensating fibers, amplifying fibers).

Chapter 3: Optical Modulation and Demodulation

- Principles of optical modulation for signal transmission (Direct modulation, External modulation, Electro-optic modulation).
- Advanced modulation formats used in Optical Networks (NRZ-OOK, RZ-OOK, CSRZ, Differential Phase Modulation DPSK).
- Techniques of optical demodulation for data recovery (coherent demodulation techniques, optical receivers: Direct detection receivers, Homodyne and heterodyne receivers).

Chapter 4: Optical Amplification and Regeneration

- Basic principles of optical amplification (stimulated emission amplification, amplification mechanisms in amplifier media, Types of optical amplifiers).
- Optical regeneration process and types of optical regenerators: (Optical Regenerator 1R (Re-Amplification only), Optical Regenerator 2R (Re-Amplification and Re-shaping), Optical Regenerator 3R (Re-Amplification, Re-shaping, and Re-Timing).
- Performance of optical amplification and regeneration systems.

Chapter 5: Passive and Active Optical Networks

- Components of passive optical networks: Optical splitters and couplers, Optical filters.
- Architecture of passive optical networks (PON): (Point-to-point architecture (P2P), Star-split passive optical network (PON), Long-reach passive optical network (LR-PON), Long-reach passive optical network with low speed (LR-EPON), Long-reach passive optical network with high speed (LR-NGPON). Application to FTTH networks.
- Components and equipment of active optical networks (Optical routers, Optical switches, Optical multiplexers, Optical amplifiers).

- Architecture of active optical networks: (Wavelength Division Multiplexing (WDM) optical networks, Optical Packet Switching (OPS) networks).
- Intelligent optical networks: SDN networks, Add/Drop components, Optical networks applied in 5G and 6G.

Travaux pratiques:

Lab1: Design of an optical transmission system based on SMF by implementing Intensity Modulation formats NRZ□OOK, RZ□OOK, CSRZ.
Lab2: Design of a high-capacity optical transmission system based on Differential Phase Modulation (DPSK) and Quadrature DPSK (QDPSK) modulation formats.
Lab3: Design of a bidirectional FTTH optical network based on BPON.
Lab4: Design of an intelligent active optical network based on the use of Add/Drop components.
Lab5: Design and implementation of an all-optical 2R regenerator

Modalités d'évaluation :
Interrogation, devoir surveillé, travaux pratiques, examen final.

Référencesbibliographiques:

- *Optical Fiber Telecommunications, Systems and Networks, Edited by Ivan P. Kaminow, Tingye Li Alan E. Willner, Elsevier 2008.*
- *CasimerDecusatis, Fiberoptic data communication: technological trends And advances 2002.*
- *Laurant Gaska, Réseaux d'accès optiques FTTH SeriesII: Technologies et composants, 2020*
- *Rajib Ramaswaki, Optical Networks: A Practical Perspective, 3rd Edition,2009*
- *Yousef. S. Kavian, Intelligent Systems for Optical Networks Design: Advancing Techniques, 2013*

SEMESTRE	Intitulé de la matière	Coefficient	Crédits
S6	**Administration of Linux systems**	**2**	**3**

VHS	Cours	Travaux Dirigés	Travaux Pratiques
45h00	1h30	-	1h30

Prérequis:

Basic understanding of computer systems.

Objectifs:

The objective of this course is to provide students with a comprehensive understanding of Linux system administration, covering installation, configuration, maintenance, and security, to prepare them for managing Linux systems in real-world environments.

Contenu de l'enseignement :

Chapter1: Introduction to Linux

1. Overview of Linux history and philosophy
2. Linux distributions and their characteristics
3. Basic Linux commands and file system navigation

Chapter 2: System Installation and Package Management

1. Installation methods for Linux distributions
2. Package management with package managers (e.g., apt, yum)
3. Software installation, updates, and removal

Chapter 3: User and Group Management

1. Understanding the concept of user accounts, group memberships, and their roles in system access.
2. Managing users and groups
3. Understanding file permissions and ownership
4. User environment configuration and customization
5. Best practices for secure user and group management

Chapter 4: File System Management

1. Understanding the Linux file system hierarchy
2. File system types and their characteristics (e.g., ext4, XFS)
3. File system maintenance, monitoring, and troubleshooting

Chapter 5: **Shell Scripting and Automation**

1. Understanding basic shell syntax and command structure.
2. Exploring text manipulation tools like cat, head, tail, and grep.
3. Utilizing aliases, tab completion, and history commands for efficient shell navigation.
4. Introduction to shell scripting concepts with basic examples.
5. Automating repetitive tasks

Chapter 6: Networking and Security

1. Configuring network interfaces and IP addressing
2. Configuring networking services (e.g., DHCP, DNS, SSH)
3. Managing firewalls and security policies (e.g., iptables, SELinux)
4. Implementing security best practices and securing Linux systems

Travaux pratiques:

Lab1: Installing and configuring a Linux distribution (eg., Ubuntu) using virtual environment.
Lab2: Managing software packages with package managers (eg. apt).
Lab3: Managing users, groups, permissions and file systems.
Lab4: Writing scripts to automate common tasks, such as file manipulation, system monitoring, or backup operations.
Lab5: Configuring networking services (e.g., DHCP, DNS) and implementing SSH access.
Lab6: Configure firewall rules (ex. using iptables) and implementing security best practices.

Modalités d'évaluation :
Interrogation, devoir surveillé, travaux pratiques, examen final.

Référencesbibliographiques:

- *RUSLING, David A. The linux kernel. 1999.*
- *NEGUS, Christopher. Linux bible. John Wiley & Sons, 2012.*
- *WARD, Brian. How Linux works: What every superuser should know. no starch press, 2021.*
- *SHOTTS, William. The Linux Command Line, https://linuxcommand.org/tlcl.php*
- *Linux Directory structure explained : A reference guide; https://www.linkedin.com/pulse/linux-directory-structure-explained-reference-guide-linux-techlab/*

SEMESTRE	Intitulé de la matière	Coefficient	Crédits
S6	**Architecture and Programming of Embedded Systems**	**2**	**3**

VHS	Cours	Travaux Dirigés	Travaux Pratiques
45h00	1h30	-	1h30

Prérequis :

Introduction aux systèmes embarqués ou cours équivalent ou expérience en programmation d'un microcontrôleur et de ses périphériques en C.

Objectifs :

Fournir aux étudiants des connaissances sur les aspects théoriques et pratiques de la conception de logiciels embarqués, en leur enseignant les méthodes et techniques de conception et de mise en œuvre de logiciels embarqués.

Contenu de l'enseignement:

Chapter 1: Introduction to embedded systems and embedded software design.
1.1. Definitions, scope and common properties of embedded systems
1.2. Purpose of Embedded Systems
1.3. Characteristics and Quality Attributes of Embedded Systems
1.4. Major Application Areas

Chapter 2: Organisations and architectures of embedded systems.
2.1. Processors memory
2.2. Buses; I/O; Interrupts
2.3. Storage systems: Flash Memory, EEPROM, and File Systems
2.4. Power supply systems.
2.5. Specific Processors, ASICs, PLDs, Commercial Off-The-Shelf Components (COTS)
2.6. Communication Interface: Serial, SPI, I2C, and CAN protocols

Chapter 3: Embedded Firmware development
3.1. Bootstrapping and initialization processes
3.2. Hardware abstraction layers and device drivers
3.3. Real-Time Operating Systems (RTOS) and scheduler sesign
3.4. Low-level peripheral control and interrupt service routines
3.5. Firmware debugging techniques and error handling strategies

Chapter 4: Embedded programming techniques
4.1. GNU Tools and Development and debugging Tools.
4.2. Introduction to Embedded C, Interfacing C with Assembly.
4.3. Embedded programming issues - Reentrancy, Portability.
4.4. Embedded Applications using Data structures.
4.4. Optimizing and testing embedded C programs.
4.5. Object Oriented programming introduction and basics
4.6. Scripting Languages for Embedded Systems - Shell scripting,
4.7. Programming basics of Python.
Prototyping for Embedded Systems

Chapter 5: Embedded Applications
5.1. Embedded Systems for Automotive Applications
5.2. Advanced Mobile and Wireless Networks

5.3. Embedded Systems in Biomedical Applications
5.4. Embedded Systems in Robotics
5.5. Embedded Systems in Smart Grid
5.6. Design of Internet of Things
Cloud Computing and Edge Computing

Travaux pratiques :

PART – A : Embedded C Programming

1. Basic programs: "Hello World", Delay Generation, and GPIO Control
2. Implementing data structures and algorithms in embedded contexts
3. Device driver development and peripheral interfacing
4. Real-Time task scheduling and multitasking implementations
5. Embedded networking protocols and IoT applications

PART – B: Hardware and Firmware Integration

1. Embedded systems debugging and hardware troubleshooting techniques
2. System integration: sensor interfacing, actuator control, and feedback loops
3. Real-time communication protocols: UART, SPI, and I2C
4. Sensor data acquisition and processing techniques
5. Design and implementation of embedded systems projects

Modalités d'évaluation :
Interrogation, devoir surveillé, travaux pratiques, examen final.

Référencesbibliographiques:

- *A.Dean, Embedded Systems Fundamentals with ARM Cortex-M based Microcontrollers: A Practical Approach, ARM Education Media, 1st Edition, ISBN 978-1-911531-03-6*
- *T. Martin, The Designer's Guide to the Cortex-M Processor Family: A Tutorial Approach, Elsevier, 2013, ISBN 978-0080982960*
- *M. Wolf, Computer as Components: Principles of Embedded Computing System Design, 4th Edition, Morgan Kaufman Publishers 2016, ISBN 978-0-12-805387-4*
- *A. Burns and A. Wellings, Real-time Systems and Programming Languages,AddisonWesley 2001, ISBN 0 201 72988*
- *R. Kamal, Embedded Systems: Architecture, Programming and Design, McGraw-Hill, 2nd Edition, 2015.*
- *M. Barr, Programming Embedded Systems in C and C ++, O'Reilly and Associates, 1999.*
- *S. Monk , "Programming the Raspberry Pi: Getting Started with Python", The McGrawHill Companies, 2013.- Jonathan W. Valvano, "Embedded Systems: Introduction to ARM Cortex-M Microcontrollers", 2018.*
- *David E. Simon, "An Embedded Software Primer", 1999.*

- *Ying Bai, "Embedded Systems Design for High-Speed Data Acquisition and Control", 2017.*
- *Joseph Yiu, "The Definitive Guide to ARM Cortex-M3 and Cortex-M4 Processors", 2013.*
- *Chris Swan, "Mastering Embedded Linux Programming", 2015.*
- *Douglas J. Smith, "Embedded Linux Development Using Yocto Project Cookbook", 2015.*

SEMESTRE	Intitulé de la matière	Coefficient	Crédits
S6	**Computer Vision**	**1**	**2**

VHS	Cours	Travaux Dirigés	Travaux Pratiques
45h00	1h30	-	1h30

Prérequis :
Digital Signal Processing, Python programming.

Objectifs:

Computer vision techniques were increasingly being used in computer graphics to create image-based models of real-world objects, and to merge real-world imagery using computational photography techniques. In wireless communications, especially in 5G, the computer vision is evolved in various applications such as autonomous/remote controlled vehicles, visuo-haptic in virtual reality, and other cyber-physical applications. Moreover, images and videos are the most shared data on IP transmissions. In this course, the student will learn the basics of image and video formation, how to extract and exploit images and videos content, how to estimation depth and motion in a scene, and how computer vision is evolved in several real-world applications.

Contenu de l'enseignement :

Chapter 1. Image and video formation

1.1 Image acquisition, formation, and digitization

1.2 The digital camera: sampling, color, compression of digitized images

1.3 Color spaces (RB, WV, YCbCr, LAB)

1.4 Concept of resolution and image quantization

1.5 Types of digital images (BMP, TIFF, JPG, GIF, and PNG)

1.6 Concepts of digital videos

1.7 Conversions of video format and frame extraction

Chapter 2. Image and video processing

2.1. Flowchart for images and videos processing.

2.2. Point operators (pixel transforms, color transforms, histogram equalization)

2.3. Preprocessing schemes (Image and video enhancement, image restoration)

2.4. Image filtering (linear filtering, band-pass filtering, bilateral filtering, nd noise removal)

2.4. Geometric transformations (Parametric transformations, Mesh-based warping)

Chapter 3. Image and video features

3.1. Image color descriptors (Color correlogram, color coherence vector, dominant color descriptor, color structure descriptor, color layout descriptor)

3.2. Texture and gradient descriptors (Haralick features, Co-occurrence matrix, Local binary patterns, histogram of oriented gradients, Scale Invariant feature transform, Wavelets….)

3.3. Ede detection (Example: Sobel and Canny filters)

3.4. Points and patches (feature detectors, features matching, large-scale matching and retrieval, feature tracking)

3.5. Lines and vanishing points (Successive approximation, Hough transform, Vanishing points)

3.6. Segmentation (Graph-based segmentation, Mean Shift, Normalized cuts)

Chapter 4. Image alignment and stitching

4.1. Pairwise alignment (2D alignment using least squares, Iterative algorithms, 3D alignment)

4.2. Image stitching (parametric motion models, rotational panoramas, Gap closing)

4.3. Global alignment (Bundle adjustment, Parallax removal, recognizing panoramas)

4.4. Applications: Panography, Video summarization and compression, photomontage,…

Chapter 5. Motion estimation

5.1. Translational alignment (hierarchical motion estimation, Fourier-based alignment, incremental refinement)

5.2. Parametric motion (Spline-based motion)

5.3. Optical flow (multi-frame motion estimation, machine learning approaches,)

5.4. Applications: Video stabilization, video object segmentation, video object tracking, optical blur estimation….

Chapter 6. Depth estimation

6.1. Epipolar geometry (rectification, plane sweep)

6.2. Sparse correspondence (3D curves and profiles, similarity measures, sub-pixel estimation)

6.3. Multi-view stereo (Scene flow, volumetric and 3D surface reconstruction, shape from silhouettes)

6.4. Monocular depth estimation

6.5. 3D reconstruction (Shape from X, 3D scanning, surface representation, volumetric representation, model-based reconstruction)

6.6. Applications (Computer vision for multimedia): Video summarization, saliency region modeling and detection, Background replacement, 3D model capture, …

Travaux pratiques:

Lab1: Introduction to image processing (Exploring OpenCV, image reading, color space conversion, histogram equalization, geometric transformations)

Lab2: Image, video filtering and edge detection (linear filtering, bilateral filtering, Gaussian filtering, Sobel filter, Canny edge detector)

Lab3: Image and video features (Haralick features, Co-occurrence matrix, LBP, HOG, SIFT)

Lab4: Transformation-based features (Hough transform, Wavelet transform)

Lab5: Image alignment, assembling and segmentation

Lab6: Motion and depth estimation

Modalités d'évaluation :

Interrogation, devoir surveillé, travaux pratiques, examen final.

Référencesbibliographiques:

- *R. Szeliski, 2022. Computer vision: Algorithms and application, Edited by Springer.*
- *M. Rever, 2018. Computer vision projects with OpenCV and Python3, Packt publishing.*
- *G.M. Farinella, R. Cipolla, S. Battiato, 2013. Advanced topics in computer vision, Edited by Springer.*
- *F. Solina, T. Albrecht, R. Klette, W. Kropatsch, 2012. Theoretical foundations of computer vision, Edited by Springer.*
- *J. Wang, J. Chang, S. Jiang, 2011. Computer Vision for multimedia applications: Methods and solutions, Edited by Information Science Reference, New York.*

SEMESTRE	Intitulé de la matière	Coefficient	Crédits
S6	**Entrepreneurship and Start-up**	**1**	**1**

VHS	Cours	Travaux Dirigés	Travaux Pratiques
22h30	1h30	-	-

Prérequis:

Legal rights of new digital technologies & Telecommunications.

Objectifs :

Les étudiants comprendront comment les technologies numériques en tant que catalyseurs permettent aux innovateurs et aux entrepreneurs d'évaluer et de concrétiser de nouvelles idées commerciales, et réaliser des produits technologiques numériques qui peuvent évoluer en permanence avec les besoins des clients.

Contenu de l'enseignement :

Chapter 1:Entrepreneurship

1.1. What are we talking about when we talk about entrepreneurship
1.2. Design thinking and entrepreneurship
1.3. Entrepreneurship and problem solving
1.4. Entrepreneurship and teamwork
1.5. Leading technology examples that are relevant to innovation and entrepreneurship such as: big data, Cloud computing, Automation and Robotics, AI, Nano technologies, 3D printing.

Chapter 2: The ideation process

2.1. Creativity workshop (brainwriting, diverging phase, reverse thinking …)
2.2. Identifying a problem and a need
2.3. An iterative process
2.4. Problem statement and value proposition
2.5. Agile method – paper prototyping

Chapter 3: **Market Analysis**

3.1. Market research- significance, impact, who and how.
3.2. Product market fit
3.3. The customer experiences
3.4. To ask the right question
3.5. Developing a Value Proposition

Chapter 4:Business model

4.1. Business model generation
4.2. Compelling business model
4.3. Emerging technologies and business innovation
4.4. Case Studies Exploration

Chapter 5:Digital Business and E-commerce

5.1. Identifying and exploiting opportunities for digital entrepreneurship
5.2. Strategies for creating competitive advantage in digital entrepreneurship
5.3. Digital marketing for entrepreneurs
5.4. Overview of the E□commerce and Tech Sector players, structure, business models, dynamics, trends 2
5.5. The legal side of innovation and entrepreneurship: intro to corporate law- the concept of legal personality, limited liability, ownership structures and implications, data protection etc.
5.6. User experience of world's most successful companies

Modalités d'évaluation :
Interrogation, examen final.

Références bibliographiques :

- *Bridge, S., O'Neill, K. and Cromie, S. (2003). Understanding Enterprise, Entrepreneurship and Small Business. London: Palgrave Macmillan.*
- *Barringer, B.R. and Ireland, R.D. (2010). Entrepreneurship: Successfully Launching New Ventures. London: Pearson.*
- *Ng, I. (2014). Creating New Markets in the Digital Economy: Value and Worth. Cambridge: Cambridge University Press.*
- *Malecki, E. and Moriset. (2007). The Digital Economy: Business Organization, Production Processes and Regional Developments. London: Taylor & Francis.*
- *Jan van den Ende (2021), Innovation Management, Macmillan International Higher Education, Red Globe Press.*
- *Sunil Gupta (2018), Driving Digital Strategy, Harvard Business Review Press.*

Programmes détaillés des matières du 7ème semestre

SEMESTRE	Intitulé de la matière	Coefficient	Crédits
S7	**RF Circuits Design**	**3**	**5**

VHS	Cours	Travaux Dirigés	Travaux Pratiques
67h30	1h30	1h30	1h30

Prérequis :

Mathematics: vector analysis, matrix…, Analog electronics, transistors, diodes, filters, electronic circuits, resonators, Electromagnetism, electromagnetic waves.

Objectifs:

Identifying different microwave components used on a front-end system radio. Learning how to design these components, which are essential to a wireless transmission chain.

Contenu de l'enseignement:

Chapter 1: Knowledge for designing a microwave component

1.1 transmission lines characteristics: equivalent circuit of a transmission line, impedance characteristic impedance, return loss, Z, Y parameters …
1.2 Smith Chart
1.3 impedance matching with stubs
1.4 S Parameters

Chapter 2 : Passive components
2.1 Designing a Waveguide: rectangular waveguide circular waveguide, modes…
2.2 Designing a planar transmission line: Microstrip line, CPS, CPW, modes …
2.3 RF Couplers
2.4 RF filters

Chapter 3: RF amplifiers
3.1 Biplolartransistor and Field-effect transistor characteristics
3.2 Designing a Power amplifier
3.3 Designing a LNA (low nose amplifier)

Chapter 4 : Oscillators and mixers
4.1 Diodes used in RF (Schottky diodes, Tunnel diodes, Gunn diodes, (IMPATT) diodes,...)
4.2 Resonant cavity principle (modes, resonant frequency, equivalent circuit,...)
4.3 Designing RF Oscillators (Oscillators with diodes, oscillators with transistors, waveguide oscillator)
4.4. Designing RF mixers (Mixers with diodes, mixers with transistors)

Chapter 5 : High power RF components
5.1. Tubes vacuum
5.2 Tube vacuum Biasing
5.3 High power tube amplifier (traveling-wave tube amplifier, klystron, magnetron,…)

Travaux pratiques:

Lab1: Designing and measuring a Microstrip line
Lab2: Designing and measuring a RF coupler
Lab3: Designing and measuring an RF amplifier
Lab4: Designing and measuring an RF oscillator
Lab5: Designing and measuring an RF mixer

Modalités d'évaluation :

Interrogation, devoir surveillé, travaux pratiques, examen final.

Référencesbibliographiques:

- *David M. POZAR, Microwave Engineering, J. Wiley and sons, New York, 1998.*
- *Paul-François COMBES, Raymond CRAMPAGNE, Circuits passifs hyperfréquences-Éléments passifs réciproques, Techniques de l'Ingénieur, 2003.*
- *GAUTIER Jean-Luc, Conception des dispositifs actifs hyperfréquences, Lavoisier, Paris, 2014.*

SEMESTRE	Intitulé de la matière	Coefficient	Crédits
S7	**Digital Communication Systems**	**3**	**5**

VHS	Cours	Travaux Dirigés	Travaux Pratiques
67h30	1h30	1h30	1h30

Prérequis :

Théorie du signal, Digital signal processing, Advanced signal analysis, Optimization techniques and algorithms, RF communication fundamentals.

Objectifs :

À travers cet enseignement, les étudiants approfondiront leur compréhension des traitements requis pour l'émission et la réception d'un signal numérique via un canal AWGN. La modulation/démodulation numérique, la détection optimale, les filtrages de mise en forme et adaptés, ainsi que l'égalisation et la synchronisation, seront détaillés pour permettre aux étudiants de maîtriser leurs principes et leur impact sur les performances des communications numériques. Des travaux pratiques expérimentaux compléteront la formation théorique, favorisant une meilleure assimilation des concepts abordés.

Contenu de l'enseignement :

Chapter 1 : Representationof NarrowbandSignals

1.1 Elements of a digital communicationchain
1.2 Signal bandwidth
1.3 Narrowbandsignals
1.4 Baseband and passbandsignals
1.5 Signal spacerepresentation

Chapter 2: Digital Modulation & Demodulation

2.1 Representation of digitally modulated signals: M-PAM, M-PSK, M-QAM, FSK
2.2 Transmission through an AWGN channel
2.3 Matched filterreceiver
2.4 I/Q demodulatorreceiver

Chapter 3: Optimal detection and performance of Communications over an AWGN Channel

3.1 Optimal detection: MAP detector, ML detector, Decision regions
3.2 Symbol error probability for optimal detection
3.3 Error probability invariance under translation and rotation
3.4 Boole's inequality and "nearest neighbor" approximation
3.5 Performance (error probability) of common digital modulations

Chapter 4: Band-Limited Digital Transmission

3.6 Nyquist criterion for interference-free symbol transmission
3.7 Nyquist filtering: raised cosine filter
3.8 Eye diagram
3.9 Nyquist filtering and spectral efficiency
3.10 Equalization techniques: linear equalization and decision feedback equalization

Chapter 5: Digital SynchronizationTechniques

4.1 Formulation of the problem
4.2 Carrier frequency synchronization
4.3 Carrier phase synchronization
4.4 Symbol timing synchronization
4.5 Frame synchronization: preamble detection

Travaux pratiques :

Lab 1: Spectral analysis of narrowband signals using a spectral analyzer and SDRs.
Lab 2: Over-the-air transmission & demodulation of digitally modulated signals using GnuRadio and SDRs.
Lab 3: Shaping (Root Raised Cosine) and matched filtering: Rolloff factor, Eye diagram and spectral efficiency over-the-air using GnuRadio and SDRs.
Lab 4: Over-the-air carrier frequency synchronization: Frequency Locked Loop (FLL) & symbol timing recovery and synchronization: Polyphase Clock Synchronization.
Lab 5: Over-the-air carrier phase synchronization: Costas Loop & Linear equalization: ZF, MMSE and LMS.
Lab 6: Over-the-air packet transmission: End to end text transmission.

Modalités d'évaluation :

Interrogation, devoir surveillé, travaux pratiques, examen final.

Référencesbibliographiques:

- *John G. Proakis, Masoud Salehi, "Digital Communications", 5th Ed, McGraw Hill, 2007*
- *Michael Rice, "Digital Communications: A Discrete-Time Approach", Prentice Hall, 2009*
- *Robert W. Heath, Digital Wireless Communication: Physical Layer Exploration Lab Using the NI USRP, National Technology and Science Press, 2012*
- *Simon Hykin, "Digital Communications Systems", Wiley, 2013.*
- *Robert W. Heath, Introduction to Wireless Digital Communication, Prentice Hall, 2017.*

SEMESTRE	Intitulé de la matière	Coefficient	Crédits
S7	**Compression and Coding**	**3**	**5**

VHS	Cours	Travaux Dirigés	Travaux Pratiques
67h30	1h30	1h30	1h30

Prérequis:
Probability and statistics, signal processing and fundamentals of information theory and coding.

Objectifs:
This lecture involves introducing students to advanced techniques used in contemporary communication systems and data processing. The adopted approach consists on providing context on the importance of modern channel coding and compression in today's digital age.

Discuss how these techniques enable efficient and reliable communication, storage, and transmission of data across various applications such as wireless communication, satellite communication, multimedia streaming, and cloud computing.
By incorporating these strategies, one could create an engaging and comprehensive learning experience that fosters a deep understanding and appreciation for modern channel coding and compression.

Contenu de l'enseignement :

Chapter 1 : Lossy compression

1.1 General concepts and definitions
1.2 Lossy Compression in Differential Coding (Differential Pulse Code Modulation (DPCM), Delta Modulation (DM), Delta-Sigma Modulation, Comparison and Applications of Digital Modulations)
1.3 Transform based methods
- 1.3.1 General scheme of compression methods based on transformations
- 1.3.2 Transformations (DCT, WT)
- 1.3.3 Quantization (Scalarquantization, vectorialquantization, Loyd-Max algorithm)
- 1.3.4 Entropic coding
- 1.3.5 Performance criteria (MSE, PSNR, CR, SSIM, …)

Chapter 2: Compression Standards

2.1 MP3
2.2 JPEG
2.3 JPEG 2000
2.4 MPEG – H265

Chapter 3: Channel coding

3.1 Reminders on correction codes
3.2 Cyclic Codes
3.2.1 Definition and Representation
3.2.2 Algebraic Encoding of Cyclic Codes
3.2.3 Syndrome Calculation and Error Detection
3.2.4 Algebraic Decoding of Cyclic Codes
3.2.5 Circuits for Cyclic Encoding and Decoding
3.2.6 Cyclic One Error Correcting Hamming Code
3.2.7 Golay Code and Fire Codes
3.2.8 Reed–Solomon Codes
3.3 Convolutional Codes
- 3.3.1 Representation and Properties
- 3.3.2 Convolutional Codes Encoding
- 3.3.3 Graphic Representation of Convolutional Codes
- 3.3.4 Code Distance and d ∞
- 3.3.5 Decoding (Viterbi Algorithm, Threshold Decoding)

3.4 Interleaving and Concatenation Code
- 3.4.1 Interleaving (convolutional interleaving, random interleaving,…)
- 3.4.2 Concatenated Codes (serial concatenation, parallel concatenation, …)

Chapter 4: Modern channel coding

4.1 Turbo codes
- 4.1.1 Definition and Encoding
- 4.1.2 Decoding (Basic Principles, Viterbi Algorithm (VA) , Bidirectional Soft Output Viterbi Algorithm, (SOVA), MAP Algorithm , MAX-LOG-MAP Algorithm)

4.2 LDPC codes (Matrix and graphical representations, LDPC coding, LDPC decoding)
4.3 Polar codes (channel polarization, polar coding procedure, polar decoding).
4.4 Applications of modern channel codes in mobile systems

Chapter 5: Joint Source and Channel Coding (3 weeks)

5.1 Introduction
5.2 Basics of joint source-channel coding (drawbacks of separate Shannon coding, background of the joint coding)
5.3 Design of the joint source-channel coding (JSCC)
5.4 JSCC design techniques (JSCC based on flow rates balancing, JSCC based on Unequal error protection, JSCC based on index assignment, JSCC based on optimized quantization for a binary channel, Joint optimization of quantifier, index assignment and modulation)

Travaux pratiques :

Lab1: Introduction to MP3 and JPEG
Lab2: Introduction to JPEG 20000
Lab3 : LDPC codes
Lab4: Cyclic codes (BCH codes)
Lab5 : Convolutional codes
Lab6 : Turbo-codes

Modalités d'évaluation : Interrogation, devoir surveillé, travaux pratiques, examen final.

Référencesbibliographiques:

1. *M. Cover and J. A. Thomas, "Elements of information theory", 2nd edition, Wiley Series in telecommunications and signal Processing, 2006*
2. *M. Barlaud, C. Labit, "Compression et codage des images et des vidéos", traité Collection IC2, Ed. Hermés, 319p, 2002.*
3. *J. C., Moreira, P. G., Farrell, "Essentials of Error-Control Coding", John Wiley and Sons, Ltd, 2006.*
4. *C. Berrou, "Codes et turbocodes", Springer-verlag France, 2007.*
5. *M. Bossert, "Channel Coding for Telecommunications", John Wiley & Sons, Ltd, UK, 1999.*
6. *A. Neubauer, J. Freudenberger and V. Kühn, "Coding Theory Algorithms, Architectures, and Applications", John Wiley & Sons, Ltd, 2007.*
7. *K. Deergha Rao, "Channel Coding Techniques for Wireless Communications", Second Edition, Springer Nature Singapore Pte Ltd., 2019.*
8. *Norbert Goertz, "Join Source-Channel Coding of Discrete-Time Signals With Continuous Amplitudes", Imperial College Press, 2007.*

SEMESTRE	Intitulé de la matière	Coefficient	Crédits
S7	**Multimedia Transmission**	**3**	**5**

VHS	Cours	Travaux Dirigés	Travaux Pratiques
67h30	1h30	1h30	1h30

Prérequis:

A basic understanding of computer science and networks is recommended, as well as familiarity with the basic principles of multimedia data compression and transmission. Prior experience with programming languages and development tools could also be beneficial.

Objectifs:

Upon successful completion of this subject, students should be able to understand the fundamental principles of multimedia transmission, master compression and streaming techniques for images, sound, and video.

Contenu de l'enseignement :

Chapter 1. Introduction to Multimedia Transmission

I.1. Introduction

- Importance de la transmission multimédia dans les réseaux modernes.
- Rôle des médias comme images, sons et vidéos dans les communications numériques.

I.2. Fundamental concepts of multimedia transmission.

I.2.1. Multimedia transmission system
I.2.2. Different multimedia transmission channels

I.3. Types of multimedia data and their uses

I.3.1. Text
I.3.2. Audio
I.3.3. Image
I.3.4. Video

I.4. Requirements of Multimedia Transmission Over Networks

I.4.1. Bandwidth Requirements
I.4.2. Low Latency Demands
I.4.3. Quality of Service (QoS) Needs
I.4.4. Scalability Considerations
I.4.5. Reliability Imperatives
I.4.6. Security Concerns

I.5. Challenges of Multimedia Transmission Over Networks

I.5.1. Bandwidth Limitations
I.5.2. Network Congestion
I.5.3. Packet Loss and Jitter
I.5.4. Interoperability Challenges
I.5.5. Synchronization Issues
I.5.6. Error Resilience
I.5.7. Resource Constraints

Chapter 2. Image Transmission

II.1. Common image formats and their characteristics.
II.2. Image processing techniques colorimetry, filtering, binarization, etc.).
II.3. Methods of Image Compression: Lossy and Lossless

II.3.1. Lossy Image Compression
- Overview of Lossy Compression
- Techniques : DiscreteCosineTransform (DCT), Quantization, Huffman Coding

- Applications and Use Cases

II.3.2. Lossless Image Compression

- Overview of Lossless Compression
- Techniques: Run-Length Encoding (RLE), Lempel-Ziv-Welch (LZW), Algorithm, Predictive Coding and Arithmetic Coding
- Applications and Use Cases

II.4. Protocols used for image transmission over IP networks.

Chapter 3. Audio Transmission

III.1. Common audio formats and their properties.
III.2. Audio compression algorithms and codecs
  III.2.1. Wave form audio codec: PCM, DPCM, ADPCM
  III.2.2. Parametric codec: CELP, MDCT
  III.2.3. Hybrid codec
III.3. Protocols for audio transmission over IP networks:
  III.3.1. Signalization protocols SIP
  III.3.2. Transport protocols RTP, RTCP.
III.4. Quality of Service (QoS) for real-time streaming.

Chapter 4. Video Transmission

IV.1. Video compression standards
  IV.1.1. Introduction to Compression Algorithms
  IV.1.2. H.264 (Advanced Video Coding - AVC)
  IV.1.3. H.265 (High Efficiency Video Coding - HEVC)
  IV.1.4. MPEG (Moving Picture Experts Group)
IV.2. Video streaming protocols over IP:
  IV.2.1. RTSP (Real-Time Streaming Protocol)
  IV.2.2. MPEG-DASH (Dynamic Adaptive Streaming over HTTP).

Chapter 5. Security in Multimedia Data Transmission

V.1. Introduction to security in multimedia data transmission.
V.2. Encryption techniques to secure images, sound, and video during transmission.
V.3. Watermarking and fingerprints.

Travaux pratiques:

Lab 1. Image Processing and Compression: Use tools for edge detection (filtering) and image compression (Python, OpenCV…)

Lab 2. Audio Compression and Transmission: Audio codecs and IP transmission (Packet Tracer).

Lab 3. Audio over IP with Wireshark using ASTERISK: Study SIP exchanges in the context of calls between different UAs and ASTERIX servers (Wireshark)**.**

Lab 4. Video Transmission and MPEG Compression: explore video transmission over IP networks and the basics of MPEG compression (VLC, Mininet or GNS3)

Lab 5. Hands-On: Building an IP Video Surveillance Network with Packet Tracer:"Explore the world of IP video surveillance and configure a comprehensive network for monitoring and recording video feeds using Packet Tracer."

Lab 6. Security in Multimedia Data Transmission: Explore encryption techniques to secure multimedia data. Use watermarks for image authentication.

Modalités d'évaluation :

Interrogation, devoir surveillé, travaux pratiques, examen final.

Référencesbibliographiques:

- *"Multimedia Communications: Applications, Networks, Protocols and Standards" by Fred Halsall*
- *"Image Processing, Analysis, and Machine Vision" by Milan Sonka, Vaclav Hlavac, and Roger Boyle*
- *"Digital Audio Watermarking Techniques and Technologies: Applications and Benchmarks" edited by Nedeljko Cvejic and Tapio Seppänen*
- *"Video Processing and Communications" by Yao Wang, Jörn Ostermann, and Ya-Qin Zhang*
- *"Augmented Reality: Principles and Practice" by Dieter Schmalstieg and Tobias Hollerer*
- *"3D Computer Vision: Algorithms and Applications" by Richard Szeliski*
- *"Streaming Systems: The What, Where, When, and How of Large-Scale Data Processing" by Tyler Akidau, Slava Chernyak, and Reuven Lax.*

SEMESTRE	Intitulé de la matière	Coefficient	Crédits
S7	**Web & Mobile Application Development**	**2**	**3**

VHS	Cours	Travaux Dirigés	Travaux Pratiques
45h00	1h30	-	1h30

Prérequis:

- Avoir réussi le module "IP Network and Service Engineering "
- Bonne compréhension des réseaux et services IP de base (TCP/IP, routage)
- Connaissance des technologies de commutation et d'adressage IP

- Notions de sécurité informatique et de pare-feu

Objectifs:

- Acquérir des compétences fondamentales en développement d'applications web et mobile.
- Maîtriser les langages et technologies web (HTML, CSS, JavaScript).
- Développer des applications mobiles natives pour Android et iOS.
- Comprendre les défis en matière de sécurité et d'accessibilité dans le développement web et mobile.

Contenu de l'enseignement :

Chapiter1 : Web Development :Front-end

1.1 Client-server communication model
1.2 HTML and CSS: Structure and layout of web pages
1.3 JavaScript : Client-sideprogramming

Chapiter 2: Web Development: Back-end
2.1 Back-end frameworks: Node.js, Angular, React, etc.
2.2 Databases and APIs
2.3 Responsive design and mobile web

Chapiter 3: Web Development: Back-end
3.1 Android: Java, Kotlin, Android Studio
3.2 iOS: Swift, Xcode
3.3 User interfaces and application design
3.4 Integration of external services (GPS, camera, etc.)
3.5 Deployment to app stores

Chapiter 4: Security and Accessibility
4.1 Web vulnerabilities and application security
4.2 Best development practices
4.3 Web and mobile application accessibility

Travaux pratiques :

Lab 1: Introduction to Web Development: HTML and CSS
Lab 2: Web Programming with JavaScript: Introduction and Interactions

Lab 3: Databases and APIs for the Web: Data Storage and Manipulation
Lab 4: Native Mobile Application Development: Android with Java/Kotlin
Lab 5: Responsive User Interface Design: Mobile-first and Best Practices
Lab 6: Security and Best Development Practices: Protecting Web and Mobile Applications

Modalités d'évaluation :

Interrogation, devoir surveillé, travaux pratiques, examen final.

Référencesbibliographiques:

- *Flanagan, D. (2020). JavaScript: The Definitive Guide, 7th Edition. Pearson.*
- *Robson, E., & Freeman, E. (2011). Head First Web Development. O'Reilly Media.*
- *Phillips, B., Stewart, C., & Marsicano, K. (2020). Android Programming: The Big Nerd Ranch Guide, 4th Edition. O'Reilly Media.*
- *Phillips, B., Stewart, C., & Marsicano, K. (2021). iOS Programming: The Big Nerd Ranch Guide, 8th Edition. O'Reilly Media.*

SEMESTRE	Intitulé de la matière	Coefficient	Crédits
S7	**Advanced IP Network and Service Engineering**	**2**	**3**

VHS	Cours	Travaux Dirigés	Travaux Pratiques
45h00	1h30	-	1h30

Prérequis:

- Avoir réussi le module "IP Network and Service Engineering "
- Bonne compréhension des réseaux et services IP de base (TCP/IP, routage)
- Connaissance des technologies de commutation et d'adressage IP
- Notions de sécurité informatique et de pare-feu

Objectifs:

- Acquérir une compréhension approfondie des technologies et protocoles IP avancés.
- Maîtriser les techniques de conception et de déploiement de réseaux et services IP

complexes.
- Être capable d'analyser et de résoudre les problèmes rencontrés dans les réseaux IP.

Contenu de l'enseignement :

Chapiter 1 : Advanced IP Networks

1.1 Advanced routing (BGP, OSPF, etc.)
1.2 IP switching (MPLS, etc.)
1.3 Virtual Private Networks (VPN)
1.4 Quality of Service (QoS)
1.5 Advanced IP Security

Chapiter 2 : Advanced IP Services
2.1 VoIP
2.2 IPTV
2.3 IP Mobility
2.4 Cloud Computing
2.5 Internet of Things (IoT)

Chapiter 3 : Advanced IP Services
3.1 IP network architectures
3.2 IP network sizing
3.3 Selection of technologies and equipment IP network deployment and configuration

Chapiter 4 : Analysis and problem resolution in IP networks
4.1 Diagnostic and troubleshooting tools
4.2 Problem-solving techniques
4.3 Best practices

Travaux pratiques :

Lab 1: Advanced Routing Configuration and Analysis (BGP, OSPF).
Lab 2: Deployment and Configuration of VPNs on an IP Network.
Lab 3: Deploy MPLS technology in a simulated network environment using GNS3.
Lab 4: VPN Setup and Performance Optimization with OpenVPN and Iperf.
Lab 5: Set up and analysis of a VoIP system using Asterisk PBX software and Wireshark.
Lab 5: Troubleshooting and Problem Solving in Complex IP Networks using Cisco Paquet Tracer.

Modalités d'évaluation :

Interrogation, devoir surveillé, travaux pratiques, examen final.

Référencesbibliographiques:

- *Davies, E., & Brooks, P. A. (2013). MPLS: Fundamentals and applications (2nd ed.). Morgan Kaufmann.*
- *Doyle, J. R., & Eggert, L. (2016). BGP: Routing the Internet (2nd ed.). Morgan Kaufmann.*
- *Crowcroft, J., & Handley, M. (2003). Quality of service in IP networks: Theory and practice. John Wiley& Sons.*
- *McCabe, J. D. (2017). IP networking: The definitive guide (3rd ed.). Morgan Kaufmann.*

SEMESTRE	Intitulé de la matière	Coefficient	Crédits
S7	**Satellite Networks**	**1**	**1**

VHS	Cours	Travaux Dirigés	Travaux Pratiques
22h30	1h30	-	-

Prérequis:

Transmission media, Antennas and Wireless propagation, Digital Communication.

Objectifs:

The objective of this course is to provide a general overview of the main characteristics of satellite networks, their architectures, and configurations.

Contenu de l'enseignement:

Chapter1 : Satellite Communication

- Satellite positioning (movement of an artificial satellite: Kepler's laws, orbital plane)
- Satellite movement trajectory. Different types of orbits (Geostationary orbit, Polar circular orbit, Inclined circular orbit, Elliptical orbits)
- Frequency bands
- Calculation of geostationaryorbit altitude

- Calculation of satellite speed
- Link budget (Main parameters of a link, attenuation, noise concept, power budget, overall budget, examples of link budget)
- Constraints of satellite solutions (Coverage, Bandwidth management, Handover, Delay)

Chapter2 :Attenuation in Radio Wave Propagation

- Introduction
- Atmosphericlosses
- Ionosphericeffects
- Rain attenuation

Chapter3 : Satellite Networks

- Introduction
- Operating Principles
- Satellite Network Architectures (Mesh Architecture, Star Architecture)
- Configuration of a Star Vsat Network (Current Model, ATM over Satellite Model)
- Geostationary Satellite Constellations (GEO)
- LEO/MEO Satellite Constellations (Iridium, Globalstar, Teledesic)

Chapter4 : Satellite Radionavigation Systems

- Terrestrial radionavigation systems (VOR, TACAN, DME, ILS, MLS, LORAN)
- Introduction to the GPS system and GPS signals (Functional architecture of a receiver)
- GPS measurement principles: pseudoranges, pseudovelocities, calculation of GPS position and speed
- Specificities of military GPS receivers: cryptographic modules, direct Y-code acquisition, jamming resistance

Modalités d'évaluation :

Interrogation, examen final.

Références bibliographiques :

- *B. R. Elbert, "The Satellite Communication Applications Handbook", Artech House, 2004.*
- *E. Altman, A. Ferreira, J. Galtier, "Les réseaux satellitaires de télécommunication", Dunod, 1999.*
- *J. Pelton, "Satellite Communications", Springer, 2011.*

SEMESTRE	Intitulé de la matière	Coefficient	Crédits
S7	**Mobile Marketing**	**1**	**1**

VHS	Cours	Travaux Dirigés	Travaux Pratiques
22h30	1h30	-	-

Prérequis :

Base des principes du marketing ainsi qu'une familiarité avec les plateformes et outils numériques.

Objectifs :

Ce cours vise à équiper les étudiants des connaissances et compétences nécessaires pour naviguer dans le paysage complexe du marketing à l'ère digitale, en se concentrant sur l'optimisation des stratégies marketing mobiles. À travers ce programme, les étudiants exploreront l'évolution du marketing mobile, apprendront à analyser l'environnement marketing dans un monde en transformation et étudieront les principes économiques sous-jacents au marketing des services mobiles.

Contenu de l'enseignement :

Chapter1 : Marketing Fundamentals

- Evolution of Mobile Marketing
- Marketing Environment in the Age of Transformation
- Path of Evolution of Mobile Marketing
- Principles of Economics for Service Mobile Marketing Theory

Chapter 2: Notions about the Services

- Overview
- App Service Operation
- Thinking Models for Developing Services
- Service Marketing Mode
- Service Value Marketing

Chapter 3: Substance Marketing

- The Directions of Mobile Substance Marketing
- Substance Management: Mobile Brand Management
- Deep Substance of Management
- Methods for Substance of Content Marketing

Chapter 4: Super User

- Vital Few
- Behavioral Characteristics of Super Users
- Application Principle of Super User: Sharing Economy
- The Marketing Law of Super Users

Chapter 5: Marketing Space

- The Evolution of Marketing Channels
- Network Marketing Space
- Marketing Space 4.0 – Mobile End-to-end Marketing
- Mobile Marketing Space Spread

Chapter 6: Global Marketing

- Reinterpreting Four Industrial Revolutions
- Age of Conflict 4.0
- Spiral Economics

Modalités d'évaluation :

Interrogation, examen final.

Références bibliographiques :

- *Rowles D., "Mobile marketing: how mobile technology is revolutionizing marketing, communications and advertising". Kogan Page Publishers. 2017.*
- *GHOSE, Anindya. TAP:" Unlocking the mobile economy". MIT Press, 2018.*
- *POYNTER, Ray, WILLIAMS, Navin, et YORK, Sue." The handbook of mobile market research: Tools and techniques for market researchers". John Wiley & Sons, 2014.*

- *KRUM, Cindy. "Mobile marketing: Finding your customers no matter where they are". Pearson Education, 2010.*

Programmes détaillés des matières du 8ème semestre

SEMESTRE	Intitulé de la matière	Coefficient	Crédits
S8	**Advanced Wireless Communications**	**3**	**5**

VHS	Cours	Travaux Dirigés	Travaux Pratiques
67h30	1h30	1h30	1h30

Prérequis:

Digital communication systems, Digital signal processing, Advanced signal analysis, Optimization techniques and algorithms, Antennas and wireless propagation.

Objectifs :

L'objectif de ce cours est de fournir aux étudiants une compréhension approfondie des principes fondamentaux et des technologies avancées dans les communications sans fil. Ce cours couvre les aspects critiques tels que la propagation des signaux, le fading multi-chemin, la modulation OFDM, les techniques à spectre étalé et les communications à antennes multiples. Il vise à équiper les futurs ingénieurs avec les compétences nécessaires pour concevoir et analyser des systèmes de télécommunication sans fil de nouvelle génération, en mettant un accent particulier sur l'innovation et l'adaptation aux évolutions technologiques rapides du secteur.

Contenu de l'enseignement:

Chapter 1: Radio Propagation Channel: Path Loss and Shadowing

1.1 Signal Propagation Characteristics
1.2 Free-Space Path Loss
1.3 Ray tracing: Two-Ray Model
1.4 Empirical Path Loss Models
1.5 Simplified Path Loss Model
1.6 Shadowing Effect: Introduction
1.7 Log-Normal Model of Shadowing Effect
1.8 Coverage Probability and Cell Coverage Area
1.9 Shadow Fading Margin

Chapter 2: Multi-path Channel Fading

2.1 Doppler Effect and Deterministic Fading
2.2 Channel Impulse Response: Statistical Characterization, Power-Delay Profile, Doppler Power Spectrum, Coherence Bandwidth, and Coherence Time of a Channel
2.3 Classification of Multi-path Channels
2.4 Channel Path Gains Statistics: Rayleigh, Rice, Nakagami-m
2.5 Channel Selectivity and Received Signal Model
2.6 Impact of Multi-path on Signal Detection

Chapter 3: Orthogonal Frequency-Division Multiplexing (OFDM)

3.1 Fundamentals of Multi-Carrier Modulation.
3.2 Multi-Carrier Modulation with Sub-Channel Overlapping.
3.3 Implementation of OFDM Transmitter-Receiver.
3.4 Channel Estimation and Equalization in OFDM.
3.5 Symbol Offset and Frequency Offset in OFDM: STO and CFO Synchronization.
3.6 Peak-to-Average Power Ratio (PAPR) Problem in OFDM.
3.7 Principle of SC-FDM Technique.

Chapter 4: Spread Spectrum Techniques

4.1 Spread Spectrum Principles.
4.2 Direct-Sequence Spread Spectrum (DSSS).
4.3 Frequency-Hopping Spread Spectrum (FHSS).
4.4 Multiuser DSSS and FHSS Systems.
4.5 Chirp Spread Spectrum.

Chapter 5: Introduction to Multiple-Antennas Communications

5.1 Motivation for Multiple-Antennas Communications.
5.2 MIMO Channel Modeling.
5.3 Beamforming Principles.
5.4 Spatial Diversity at the Transmitter and Receiver.
5.5 Multiplexing Diversity of MIMO Systems.
5.6 Diversity-Multiplexing Tradeoff of MIMO Systems.

Travaux pratiques:

Etablisement :
*Intitulé : **A**dvanced **T**echnologies in **T**elecommunications* *.Année universitaire :*

Lab 1: CombinedSimplified Path Loss and log-normal shadowing: simulation and experimental study.
Lab 2: Digital modulated signal transmission throughRayleigh and Ricemulti-path channels.
Lab 3: End to endOFDM transceiver design using GnuRadio and SDRs: text and image transmission.
Lab 4: Over-the-airFHSS transmission using GnuRadio and SDRs.
Lab 5: Digital phased array beamformer design using SDRs.

Modalités d'évaluation :
Interrogation, devoir surveillé, travaux pratiques, examen final.

Référencesbibliographiques:

- *David Tse and Pramod Viswanath, "Fundamentals of Wireless Communications", Cambridge University Press, 2005.*
- *Andrea Goldsmith, "Wireless Communications", Cambridge University Press, 2005.*
- *Aditya K. Jagannatham, "Principles of Modern Wireless Communication Systems", McGraw Hill Education, 2016.*
- *Quasimi Chaudhari, "Wirless Communications from the Ground Up : An SDR perspective", Wirelesspi, 2018.*
- *Robert W. Heath JR and Angel Lozano, "Foundations of MIMO Communications", Cambridge University Press, 2019.*

SEMESTRE	Intitulé de la matière	Coefficient	Crédits
S8	**AI-Based Machine Learning**	**3**	**5**

VHS	Cours	Travaux Dirigés	Travaux Pratiques
67h30	1h30	1h30	1h30

Prérequis: The prerequisite for following this course is a basic understanding of probability and statistics.

Objectifs:
The proposed course aims to impart the main concept of machine learning applicable to various domains, with a specific focus on telecommunication applications. At the end of this course, the student is able to handle machine learning algorithms for various applications.

Contenu de l'enseignement :
Chapter 1 : Basic Notions of Artificial Intelligence

1.1 Concept of Artificial Intelligence (AI)
1.2 Components of the Human Intelligence
1.3 Design of AI System (Objective, Elements of AI, Machine Learning)

1.4 Machine Learning Approaches: Unsurpervised versus Supervised Learning
1.5 Applications of AI

Chapter 2: Unsupervised Learning Based Clustering
2.1 Introduction
2.2 Taxonomy of Clustering Algorithms
2.3 Partional Clustering (K-Means)
2.4 Hierarchical Clustering
2.5 Density-Based Clustering
2.6 Distribution-Based Clustering

Chapter 3: Supervised Learning Based Regression
3.1 Introduction
3.2 LinearRegression
3.3 Multiple LinearRegression
3.4 Polynomial Regression

Chapter 4: Supervised Learning Based Classification
4.1 Introduction
4.2 Taxonomy of Classification Algorithms
4.3 Non ParametricModels
4.3.1. K-Nearest Neighbors (KNN)
4.3.2. DecisionTrees (DT)
4.3.3. Random Forest (RF)
4.4 ParametricModels
4.4.1. LogisticRegression
4.4.2. SupportVector Machines

Chapter 5: Artificial Neural Networks
5.1 Introduction
5.2 Artificial Neural Representation : The Perceptron
5.3 Review of the Gradient Descent Algorithm
5.4 Architecture and Optimization of the Single-Layer Perceptron
5.5 Architecture and Optimization of the Multi-Layer Perceptron

Travaux pratiques:
Lab1: Toolkits for machine learning (Tensorflow, Keras, PyTorch, Sklearn), Dataset preparation.
Lab2: Evaluation of diverse clustering algorithms (K-Means, DBSCAN, Agglomerative, ...).
Lab3: Application of the regression models for prediction (Churn prediction, Power signal prediction, ...).
Lab4: Exploring algorithms for non-parametric models for signal and/or image classification.
Lab5: Exploring algorithms for parametric models for signal and/or image classification.
Lab6: Artificial neural networks for classifying telecommunication signals, detection of radio interference, etc.

Modalités d'évaluation :

Interrogation, devoir surveillé, travaux pratiques, examen final.

Référencesbibliographiques:

- *Introduction to Statistical Learning*
- *https://web.stanford.edu/~hastie/isl/.*
- *Pattern Recognition and Machine Learning*
- *http://users.ece.cmu.edu/~koopman/pattern_recognition/.*
- *Neural Networks and Deep Learning*
- *http://nnfs.io/.*
- *Understanding Machine Learning: From Theory to Algorithms*
- *https://github.com/alexeygrigorev/ml-from-scratch.*

SEMESTRE	Intitulé de la matière	Coefficient	Crédits
S8	**Design of Mobile Networks**	**3**	**5**

VHS	Cours	Travaux Dirigés	Travaux Pratiques
67h30	1h30	1h30	1h30

Prérequis:

Basic understanding of networking concepts and wireless system, Knowledge on digital communication systems, antennas and wireless propagation.

Objectifs:

This course aims to provide students with a thorough understanding of fundamental modern mobile network. It covers the evolution of mobile network technologies from 2G to 5G and beyond, focusing on key components and architectural aspects. Students will learn how to plan, deploy, and optimize mobile networks, incorporating the latest advancements and anticipating future trends.

Contenu de l'enseignement :

Chapter1: Introduction to Mobile Networks

1. Overview of mobile network generations (2G to 5G)
2. 3GPP standards and their evolution
3. Key concepts and components of mobile networks

Chapter 2: 4G LTE Fundamentals

1. LTE architecture and components
2. LTE radio access network (RAN)
3. LTE Core Network

4. LTE Air Interface (OFDM, LTE frame, Physical ressources, Channels, …)
5. LTE advanced and LTE Advanced Pro

Chapter 3: 5G Fundamentals

1. From 4G to 5G
2. 5G use case scenario (eMBB, URLLC, and mMTC)
3. Key Technologies Enabling 5G (mmWave spectrum, massive MIMO, beamforming, network slicing).
4. 5G (RAN) New Radio (standalone and non-standalone)
5. Network Slicing principle
6. 5G Core Network (Service-Based Architecture (SBA), Network Function Virtualization (NFV) concept)
7. Co-existence between NR and LTE
8. 5G Deployment and Challenges

Chapter 4: Mobile network planning & optimization

1. Overview of 4G RAN planning process
2. Pre-planning (Coverage & capacity dimensioning)
3. Detailed planning (PCI/RSI planning)
4. Post planning (optimization)
   - ✓ Key performance indicators
   - ✓ Optimization of Accessibility, Retainability, Mobility, Integrity, Availability and Utilization
5. Overview of 4G Core Network planning
6. Network Planning Consideration in 5G

Chapter 5: Towards 6G Networks

1. Drivers and timeline of 6G
2. Potential technological advancements in 6G
3. Challenges and opportunities of 6G

Travaux pratiques :

Lab1: Hands-on Atoll planning tools
Lab2: LTE network dimensioning (ex. with RND tool) and cells planning using Atoll
Lab3: Propagation model calibration and LTE PCI/RSI planning using Atoll
Lab4: 5G NR planning using Atoll
Lab5: 5G network deployment using Open-Air Interface.

Modalités d'évaluation :
Interrogation, devoir surveillé, travaux pratiques, examen final.

Référencesbibliographiques:

- *Rappaport, Theodore S. Wireless communications: principles and practice. Vol. 2. New Jersey: prentice hall PTR, 1996.*
- *Sauter, Martin. From GSM to LTE-advanced Pro and 5G: An introduction to mobile networks and mobile broadband. John Wiley & Sons, 2017.*
- *Dahlman, Erik, et al. 3G evolution: HSPA and LTE for mobile broadband. Academic press, 2010.*
- *Dahlman, Erik, Stefan Parkvall, and Johan Skold. 4G: LTE/LTE-advanced for mobile broadband. Academic press, 2013.*
- *Ali-Yahiya, Tara. Understanding LTE and its Performance. Springer Science & Business Media, 2011.*

SEMESTRE	Intitulé de la matière	Coefficient	Crédits
S8	**IoT Networks**	**3**	**5**

VHS	Cours	Travaux Dirigés	Travaux Pratiques
67h30	1h30	1h30	1h30

Prérequis:

- Bonne compréhension des réseaux et services IP de base (TCP/IP, routage)
- Connaissance des technologies de commutation et d'adressage IP
- Connaissances de base en électronique et systèmes embarqués
- Notions de sécurité informatique et de pare-feu

Objectifs:

- Acquérir une compréhension approfondie des technologies et protocoles réseaux pour l'IoT.
- Maîtriser les architectures et les solutions de communication pour l'IoT.
- Développer des compétences en sécurité et en gestion des réseaux IoT.

Contenu de l'enseignement :

Chapiter1: IoT network architectures

1.1 Definition of IoT and its characteristics
1.2 Centralized and decentralized architectures
1.3 Fog computing and Edge computing
1.4 Communication models (client-server, publish-subscribe, etc.)

Chapiter 2: Communication technologies for IoT

2.1 Short-range networks (LoRaWAN, Zigbee, Bluetooth, etc.)

2.2 Cellular networks (NB-IoT, LTE-M, etc.)
2.3 Wi-Fi and LPWAN networks
2.4 Choosing a communication technology

Chapiter 3: IoT network protocols

3.1 MQTT, CoAP, AMQP and other protocols
3.2 Operation and comparison of protocols
3.3 Choosing a protocol

Chapiter 4: IoT network security

4.1 Vulnerabilities and attacks specific to IoT
4.2 Security solutions (authentication, encryption, etc.)
4.3 Best practices for IoT network security

Chapiter 5: IoT network management

5.1 Monitoring and management tools
5.2 Software and configuration updates
5.3 Troubleshooting
5.4 Analysis of real case studies
5.5 Discussion of challenges and solutions

Chapter6 : IoT applications

6.1 Smart Homes: Explore applications, network considerations, and real-world examples of smart home technology.
6.2 Smart Cities: Discuss applications, network challenges, and real-world smart city initiatives.
6.3 Industrial IoT (IIoT): Explore applications, network needs, and real-world examples of IIoT implementations.
6.4 Industry 4.0: Discuss how Industry 4.0 leverages IoT for automation, data analytics, and advanced manufacturing processes, highlighting real-world examples of its implementation.
6.5 Healthcare and Wellness: Discuss applications, network considerations, and real-world examples of IoT in healthcare.
6.6 Transportation and Logistics: Explore applications, network needs, and real-world examples of IoT in transportation and logistics.

Travaux pratiques:

Lab 1: Implement a centralized and decentralized IoT architecture using simulation platforms (e.g., Cisco Packet Tracer).
Lab 2: Develop an IoT application using the client-server communication models.
Lab 3: Configure and test a LoRaWAN network for sensor data collection.
Lab 4: Compare the range and power consumption of Bluetooth and Zigbee technologies for a home automation application.

Lab 5: Implement and compare the MQTT and CoAP protocols for communication between connected objects.

Modalités d'évaluation :

Interrogation, devoir surveillé, travaux pratiques, examen final.

Référencesbibliographiques:

- *D. Minoli, Building the Hyperconnected Society: A Scalable and Sustainable Approach to IoT and 5G, CRC Press, 2023.*
- *M. S. Obaidat et al., Internet of Things: Concepts, Technologies, and Applications, CRC Press, 2023.*
- *S. S. Gill et al., IoT Security: Advances and Challenges, CRC Press, 2023.*
- *J. Granjal et al., Internet of Things: Fundamentals, Applications, and Challenges, Springer, 2017.*

SEMESTRE	Intitulé de la matière	Coefficient	Crédits
S8	**SoC FPGA for Embedded Systems**	**2**	**3**

VHS	Cours	Travaux Dirigés	Travaux Pratiques
45h00	1h30	-	1h30

Prérequis:

- Familiar with real-time embedded systems and hardware/software design
- Knowledge on combinatoriallogic
- Practical knowledge on C / C++, python, software development and debugging.
- Understanding of digital logic design
- Experience with microcontroller/microprocessor programming and interfacing.

Objectifs:

To learn SoC and SoC FPGA architectures used in embedded systems. To learn how to manipulate and to program SoC FPGA, using the appropriate software, to cotrol different electronic systems. Understanding methods and techniques of designing and implementing embedded systems.

Contenu de l'enseignement :

Chapter1: System on chip and FPGA

1.1. SoC architecture

1.2. FPGA architecture

1.3. Most common Soc and FPGA used for Embedded systems: AMD; Apple; Broadcom ;Intel ;Nvidia ; Qualcomm ; Samsung ; Texas Instrument,…

1.4. Uses of SoC and FPGA: especially for Embedded systems applications

1.5. Advantages and disadvantages of SoC and FPGA

1.6. Integration in system Design, Embedded system design

Chapter 2: SoC FPGA

2.1. SoC FPGA architecture

2.1. Different SoC FPGA: APSoC, MPSoC, RFSoC, …

2.2. Zynq: ARM and FPGA integrated in a single chip.

2.3. SoC FPGA Programming

2.3.1. Programming ARM of the zynq (with C/C++, python…)

2.3.2 Programming FPGA of the zynq (with VHDL, Verilog…)

2.3.3 Communication protocols and interfaces between the CPU and the FPGA (Axi interfaces)

Chapter 3: Software and tools for SoC FPGA

3.1. Different CAD, EAD, IDE for SoC FPGA: Simulators, translation tools, debugging tools, ...

3.2. Xilinx Software overview: Vivado and Vitis Overview

3.3. Programming Zynq with IP block design of Vivado

3.4. Communicate between ARM processor and Digital Logic inside FPGA

3.5. Machine learning and AI with SoC FPGA

Chapter 4: Embedded System Design

4.1. Development, Implementation and Testing

4.2. Embedded system design and development lifecycle model

4.3. Creating an embedded system architecture

4.5. Issues in Hardware-Software design and co-design.

4.6. Implementing the design

Travaux pratiques :

Each student will select a topic related to embedded systems and applications and develop an embedded product/system following the embedded system design principles:

- Write VHDL and C language codes to implement Digital system on FPGA devices.
- Use an A/D converter (Codec) to read analog signals into FPGA board
- Generate pulse-width-modulation (PWM) signals on a FPGA board for controlling the speed of a DC motor or the position of a servo
- Describe how to design using FPGA with microcontroller core.
- Work in a team environment to design a microprocessor-based system and communicate the results in a written report and an oral presentation

Lab 1: Switches, LED Lights and Mux using VHDL and/or Verolog programming

Lab 2: Full adder design with 7 seg display

Lab 3: Flipflop, Registers for a complex circuit design

Lab 4: Integrate a camera and LCD panel display

Lab 5: Micro Blaze Processor based Embedded system design on Xilinx.

Lab 6: Use of internal ARM cortex processor

Lab 7: Communicate between ARM processor and Digital Logic inside FPGA

Lab 8 : Neural networks on FPGA

Modalités d'évaluation :

Interrogation, devoir surveillé, travaux pratiques, examen final.

Référencesbibliographiques:

- *Daniele Lacamera: Embedded Systems Architecture: Explore architectural concepts, pragmatic design patterns, and best practices to produce robust systems, May 30, 2018*
- *Derek Murray: A Practical Introduction to the Xilinx Zynq-7000 Adaptive SoC: Bare-Metal Fundamentals, August 29, 202*
- *Louise H. Crockett, The Zynq Book: Embedded Processing with the Arm Cortex-A9 on the Xilinx Zynq-7000 All Programmable Soc, Strathclyde Academic Media; Illustrated edition (July 14, 2014)*
- *Blaine Readler, VHDL by Example: A Concise Introduction for FPGA, Full Arc Press 2014; First Edition*
- *Blaine Readler, Verilog by Example: A Concise Introduction for FPGA Design First Edition, Full Arc Press; First Edition*
- *Crockett H Louise, Northcote David, Ramsay Craig, Exploring Zynq MPSoCWith PYNQ and Machine Learning Applications 2019*

SEMESTRE	Intitulé de la matière	Coefficient	Crédits
S8	**SDR-based Design for RadioCom**	**2**	**3**

VHS	Cours	Travaux Dirigés	Travaux Pratiques
45h00	1h30	-	1h30

Prérequis:

RF communication fundamentals, Digital signal processing, Antennas and wireless propagation, Digital communication systems, RF circuits design, Architectures and Programming of Embedded Systems.

Objectifs :

Ce cours a pour objectif de fournir aux étudiants une compréhension approfondie et pratique des principes fondamentaux et des applications avancées des SDR. Le cours couvre à la fois les concepts théoriques et les compétences pratiques nécessaires pour concevoir, développer, et optimiser des systèmes de communication basés sur les SDR.

Contenu de l'enseignement :

Chapter 1: Introduction to Software Defined Radios

1.1 Most important SDR Milestones
1.2 What is SDR?
1.3 Motivation of SDR usage.
1.4 Common SDR software tools.
1.5 Host-based vs embedded SDRs.

Chapter 2: Understanding SDR Hardware

2.1 RF front-end: Direct conversion (Zero IF) vs direct RF sampling architectures.
2.2 Tunable RF front-end elements: Power Amplifier (PA), Low Noise Amplifier (LNA), RF mixer and Local Oscillator (LO).
2.3 Toward the digital back-end: Low pass filtering and ADC/DAC.
2.4 Digital back-end: Digital Down/Up Converter (DDC/DUC) structure.
2.5 Digital back-end host interfaces.
2.6 Sample rate and system bandwidth: some basic rules.
2.7 Difference between common SDR platforms: how to choose a platform?

Chapter 3: SDR-based RadioCom Prototyping

3.1 Software Tools and Frameworks for SDR Development
3.2 Designing an SDR Prototype: Step-by-step guide on setting up a software-defined radio system from scratch, including hardware selection and software configuration.
3.3 Fundamentals of Signal Processing in SDR: Overview of basic signal processing techniques essential for SDR prototyping.
3.4 Experimenting with SDR: Practical radio communication protocols using SDR

3.5 Debugging and Optimization: Techniques for troubleshooting common issues in SDR prototypes and optimizing performance for real-world applications.

Chapter 4: Advanced SDR applications

4.1 SDR-based Testbeds for Repeatable Experimentation in Wireless Systems
4.2 MIMO Technology in SDR
4.3 Cognitive radio capabilities in SDR
4.4 Integration with IoT and Wireless Sensor Networks
4.5 Future Trends in SDR Technology

Travaux pratiques:

Lab 1: Hands-on with SDR Platforms and Gnu-Radio: Building a Spectrum Analyzer and Investigating Wireless Signals and RF Spectrum.
Lab 2: Flexibility of a software-defined radio design: FM Transmitter-Receiver and 2-Channel FM Receiver.
Lab 3: Detection and Decoding of a Digital Transmission: OOK (On-Off Keying) Receiver Design
Lab 4: Digital Transceiver Design: PSK Modulation.
Lab 5: Packet Transmission Design: End to end OFDM transmission.

Modalités d'évaluation :

Interrogation, devoir surveillé, travaux pratiques, examen final.

Référencesbibliographiques:

- *Quasimi Chaudhari, "Wirless Communications from the Ground Up: An SDR perspective", Wirelesspi, 2018.*
- *WYGLINSKI, Alexander M., GETZ, Robin, COLLINS, Travis, et al. "Software-defined radio for engineers ". Artech House, 2018.*
- *Stewart, Robert W. Barlee, Kenneth W. and Atkinson, Dale S. W. and Crockett, Louise H. "Software Defined Radio using MATLAB & Simulink and the RTL-SDR ", Strathclyde Academic Media, Glasgow, 2015.*
- *Robert W. Heath, Digital Wireless Communication: Physical Layer Exploration Lab Using the NI USRP, National Technology and Science Press, 2012.*

SEMESTRE	Intitulé de la matière	Coefficient	Crédits
S8	**Fieldbus Systems**	**1**	**1**

VHS	Cours	Travaux Dirigés	Travaux Pratiques
22h30	1h30	-	-

Prérequis:

Tran Understanding of different types of networks.

Objectifs:

The objective of this course is to explore fieldbus systems, which involve connecting multiple entities of the same system on a common communication medium, for instance, within a limited geographical area (factory, workshop, automotive, embedded electronics...), taking into account real-time network reduction or expansion.

Contenu de l'enseignement:

Chapter1: Introduction to Fieldbuses

Definition of a fieldbus, Advantages and disadvantages, History: The 4-20 mA current loop, Standardization of fieldbuses, OSI Model vs. Fieldbus Model

Chapter 2: Different Fieldbus Systems

WorldFIP, INTERBUS, CAN, LonWorks, Profibus, Ethernet, Other fieldbus systems

Chapter 3: The Modbus 485 Bus

Recap of the RS232 standard, The RS485 connection, The Modbus protocol, Modbus addressing and frame structure

Chapter 4: CAN or Controller Area Network

Overview of CAN, CAN OSI Models, CAN data frames, Media access, Data rates, CAN hardware, Comparison between CAN and the Ethernet 802.3 standard, CANopen

Chapter 5: Profibus or Process Field Bus

Overview of Profibus, The three types of Profibus, Characteristics, media, Data rates, Evolution

Chapter 6: Industrial Wireless Communication Protocols (Wireless HART)

Requirements for wireless fieldbuses, HART and Wireless HART, Wireless HART protocol stack, Message format, Wireless HART spectrum

Modalités d'évaluation :

Interrogation, examen final.

Références bibliographiques :

- *Auteurs : groupe de travail Ciam. '' Réseaux de terrain. Critères de sûreté de fonctionnement''. Editeur : Hermès. Annéed'édition 2009.*
- *Jean-François Hérold, Olivier Guillotin, Patrick Anaya. '' Informatique industrielle et réseaux''. EditeurDunod. Annéed'édition 2010.*

SEMESTRE	Intitulé de la matière	Coefficient	Crédits
S8	**Compliance with Standards and Rules of Ethics and Integrity**	**1**	**1**

VHS	Cours	Travaux Dirigés	Travaux Pratiques
22h30	1h30	-	-

Prérequis:

Objectifs:

Contenu de l'enseignement :

Modalités d'évaluation :
Interrogation, examen final.

Références bibliographiques :

Programmes détaillés des matières du 9ème semestre

SEMESTRE	Intitulé de la matière	Coefficient	Crédits
S9	**AI-based Deep Learning for Telecommunications**	**3**	**5**

VHS	Cours	Travaux Dirigés	Travaux Pratiques
67h30	1h30	1h30	1h30

Prérequis:

The prerequisite for following this course isAI-Based Machine Learning.

Objectifs:

The proposed course aims to impart the main concept of contemporary and sophisticated machine learning applicable to various domains. At the end of this course, the student is able to handle contemporary machine learning algorithms for various applications.

Contenu de l'enseignement:

Chapter 1: Overview of Contemporary Machine Learning

1.1 Introduction
1.2 Deep Learning
1.3 Reinforcement Learning
1.4 Unsupervised Learning BasedAutoencoder

Chapter 2: Deep Learning Based on Convolution Neural Networks

2.1 Introduction to Convolutional Neural Networks (CNN)
2.2 Architecture of a CNN (Convolution, Rectification, Batch Normalization, Pooling, ...)
2.3 LossFunction and Optimization
2.4 Hyperparameter Fine-Tuning
2.5 Architecture Examples (VGG, ResNet, AlexNet, ...)

Chapter 3 : Recurrent Neural Networks

3.1 Introduction to Recurrent Neural Networks (RNN)
3.2 Configurations of RNN (One to Many, Many to One, Many to Many)
3.3 Architectures of RNN (GRU, LSTM, BI-LSTM)
3.4 LossFunction and Optimization

Chapitre4 : Reinforcement Learning Introduction to Reinforcement Learning

4.1 Components of Reinforcement Learning
4.2 Q-Learning Algorithm
4.3 Deep Q-Learning

Chapitre 5: Advanced learning architectures

5.1 Introduction
5.2 Architecture of Autoencoders (Encoder and decoder, Convolutional Autoencoders)
5.3 Lossfunction and Optimization
5.4 Tranformerarchitectures : Vision Transformer (embedding, self-attention, multihead attention, residual stream view, transformer encoder and decoder), Large Language Models(LLM with transformers, generation by sampling), Training transformers.

Travaux pratiques :

Lab1: Toolkits (Tensorflow, Pytorch, Sklearn, Pandas) and dataset preparation.
Lab2: Exploring CNN for Signal and Image classification: Object classification, Identification of the modulation type, ...
Lab3: Exploring RNN for Various Telecommunication Applications: Network traffic predictions, Call drop prediction, Fault detection and Diagnostic, ...
Lab4: Exploring Q-Learning for Telecommunications: Anomaly detection, network routing optimization, Network optimization for IoT, ...
Lab5: Exploring Deep Q-Learning for Telecommunications: Anomaly detection, network routing optimization, Network optimization for IoT, ...
Lab6: Applications of Convolutional auto-encoders and TransformersinTelecommunication tasks: Compression and reconstruction, Anomaly detection, Feature learning and extraction, etc.

Modalités d'évaluation :
Interrogation, devoir surveillé, travaux pratiques, examen final.

Référencesbibliographiques:

1. *Neural Networks and Deep Learning*
http://static.latexstudio.net/article/2018/0912/neuralnetworksanddeeplearning.pdf
2. *Applied Deep Learning*
https://www.programmer-books.com/wp-content/uploads/2018/12/Applied-Deep-Learning.pdf
3. *Introduction to Autoencoders*
https://pyimagesearch.com/2023/07/10/introduction-to-autoencoders/
4. *ReinforcementLearning: An Introduction*
https://readyforai.com/download/reinforcement-learning-an-introduction-2nd-edition-pdf/

SEMESTRE	Intitulé de la matière	Coefficient	Crédits
S9	**Wireless SensorNetworks**	**3**	**5**

VHS	Cours	Travaux Dirigés	Travaux Pratiques
67h30	1h30	1h30	1h30

Prérequis :

Connaissances de base en réseaux de communication, en particulier sur les topologies, les protocoles et les modèles OSI/TCP-IP ; compréhension de l'électronique et des capteurs ; connaissances en programmation (ex. C, Python).

Objectifs :

Ce cours vise à fournir une compréhension approfondie des réseaux de capteurs sans fil (WSN), en couvrant les concepts fondamentaux, l'architecture, et les protocoles de communication utilisés. Les étudiants apprendront les techniques d'efficacité énergétique et de gestion de l'alimentation et exploreront également les sujets avancés tels que la localisation, la synchronisation et l'intelligence l'IA, en mettant l'accent sur les applications réelles. À la fin du cours, les étudiants seront capables de concevoir, mettre en œuvre et évaluer des WSN économes en énergie, intégrés à des technologies avancées.

Contenu de l'enseignement :

Chapter1: Fundamentals of WSN

1. Introduction to WSNs: Definition and Characteristics, applications of WSNs
2. Architecture of WSNs: Network topologies, sensor node architecture, communication protocols
3. Sensor node hardware: Sensors and actuators, microcontrollers and processors, power supply and energy harvesting
4. WSN operating systems and platforms: Overview of popular WSN OS (TinyOS, Contiki, RIOT), development tools and simulation Platforms
5. Case Studies and Real-world Applications (Smart Agriculture and Environmental Monitoring, Healthcare and wearable sensors, …)

Chapter 2: Networking and Communication Protocols for WSN

1. Physical Layer and MAC Protocols
   - Wireless communication technologies (IEEE 802.15.4, ZigBee, Bluetooth, LoRa)
   - Medium Access Control (MAC) protocols for WSNs
2. RoutingProtocols in WSNs
   - Data-centric, Hierarchical, and Location-based Routing
   - Energy-efficient RoutingProtocols
3. Transport Layer Protocols
   - Reliability and congestion control
   - TCP/UDP in WSNs
4. Application Layer Protocols
   - Data aggregation and dissemination protocols
   - Protocols for Specific Applications (e.g., CoAP, MQTT)

Chapter 3: Energy efficiency and power management in WSN

1. Energy Consumption in WSNs
    - Sources of energyconsumption
    - Energy models for sensornodes
2. Energy-efficient Protocols and Algorithms
    - MAC and routing protocols for energy efficiency
    - Data aggregation techniques
3. Power Management Techniques
    - Duty cycling and sleepscheduling
    - Energy harvesting techniques
4. Energy-aware system design
    - Hardware and software co-design
    - Low-power electronics and energy-efficient algorithms

Chapter 4: Advanced topics and applications in WSN

1. Localization and Tracking in Sensor Networks
2. State Estimation in Sensor Network
3. Security of Sensor Networks
4. Advanced sensing and actuation
5. Machine learning and AI in WSNs
6. Collaborative Signal Processing in Sensor Networks

Travaux pratiques:

Lab 1: Introducing WSN fundamentals and simulation tools by setting up and analyzing a basic WSN simulation (e.g., NS-3, OMNeT++, TinyOS and ContikiOS).
Lab 2: Exploring sensor node hardware components and develop a basic sensor node application using Arduino/Raspberry Pi.
Lab 3: Implementing different wireless communication technologies and MAC protocols (e.g., IEEE 802.15.4 (ZigBee)).
Lab 4: Implementing and evaluating various routing protocols used in WSNs (e.g., Directed Diffusion, LEACH, GPSR).
Lab 5: Exploring and implementing energy-efficient protocols and power management techniques (e.g., Evaluating energy consumption of different MAC and routing protocols.).

Modalités d'évaluation :
Interrogation, devoir surveillé, travaux pratiques, examen final.

Références bibliographiques :

- *Fahmy, Hossam Mahmoud Ahmad. Wireless sensor networks. Berlin/Heidelberg, Germany: Springer International Publishing, 2020.*
- *Boukerche, Azzedine. Algorithms and protocols for wireless sensor networks. 2009.*
- *El Emary, Ibrahiem MM, and S. Ramakrishnan. Wireless Sensor Networks. Boca Raton, FL, USA: CRC press, 2013.*
- *El-Bendary, Mohsen AM. "Developing security tools of WSN and WBAN networks applications." (2015).*
- *Kurniawan, Agus. Practical Contiki-NG: programming for wireless sensor networks. Apress, 2018.*

SEMESTRE	Intitulé de la matière	Coefficient	Crédits
S9	**Fundamentals of NetworksSecurity**	**3**	**5**

VHS	Cours	Travaux Dirigés	Travaux Pratiques

Etablisement :
*Intitulé : **A**dvanced **T**echnologies in **T**elecommunications* *.Année universitaire :*

67h30	1h30	1h30	1h30

Prérequis:

Basic understanding of computer networks and operating systems, Familiarity with programming concepts, Proficiency in using basic network tools, Understanding of web technologies.

Objectifs:

The objective of this course is to provide students with a comprehensive understanding of key concepts and practices in cyber security, network and system security, including cryptography, threat detection, network security principles, wireless network security, system and application security. Through hands-on labs, students will gain practical skills in designing, deploying, and managing secure network and system environments.

Contenu de l'enseignement :

Chapter1: Introduction to Cyber Security

1. Overview of Cyber Security
2. Importance of Cyber Security
3. Confidentiality, Integrity, and Availability (CIA) principle
4. Security Goals and Objectives
5. Key Concepts and Terminology

Chapter 2: Cryptography Basics

1. Symmetric and Asymmetric Encryption
2. Digital Signatures and Certificates
3. PKI and key distribution
4. Cryptographic Protocols (e.g., SSL/TLS)

Chapter 3: Threats and vulnerability

1. Common Cyber Threats (e.g., Malware, Phishing, MiTM, DoS)
2. Attack Vectors and Techniques (e.g., Social Engineering, Password Attacks)
3. Vulnerability Assessment and Management

Chapter4: Network Security

1. Network security concepts: Network topology, security perimeter, segmentation, firewalls.
2. Firewalls: Types and architectures
3. Intrusion Detection and Prevention Systems (IDS/IPS): Types, deployment strategies.
4. Virtual Private Networks (VPNs)
5. Network Security Tools: Packet capture and analysis tools (e.g., Wireshark), vulnerability scanners.

Chapter 5: Wireless Network Security

1. Wireless Security Threats and Vulnerabilities (Eavesdropping, rogue access points, WEP weakness)
2. Wireless Security Protocols (e.g., WPA2, WPA3)
3. Securing wireless Access Points (AP placement, SSID, encryption, MAC filtering)
4. Best Practices for Securing Wireless Networks

Chapter 6: Security of Systems and Applications

1. User and Group Management: Access Control Lists (ACLs), Permissions, Password Policies
2. Hardening Operating Systems: Disabling Unnecessary Services, Closing Security Gaps
3. Patch Management: Importance of Timely Updates for Operating Systems, Drivers, and Firmware
4. Web Application Security: Common Attacks (e.g., SQL Injection, Cross-Site Scripting), Mitigation Techniques
5. Secure Software Development: Principles and Practices
6. Secure Coding Concepts
7. Security Assessment and Testing Methods

Travaux pratiques:

Lab1: Implementation of symmetric and asymmetric encryption algorithms in Python to secure communication.
Lab2: Simulation of Malware Infection (eg. Trojan) using Kali Linux and Phishing Attack using phishing kit (eg., KnowBe4, Gophish).
Lab3: Configuration of a Firewall and creation of rules in a simulated network environment.
Lab4: Set up of VPN server (e.g., OpenVPN) and configuration of clients to connect securely, test VPN connectivity and data encryption.
Lab5: Setup of a wireless network with security vulnerabilities (e.g., WEP encryption, open SSID), demonstration of attacks (e.g., packet sniffing), and implementation of security measures (e.g., WPA2 encryption, MAC filtering).
Lab6: Exploration of web application security vulnerabilities (e.g., SQL injection, XSS attacks) and secure coding practices.

Modalités d'évaluation :

Interrogation, devoir surveillé, travaux pratiques, examen final.

Références bibliographiques :

- *SINGER, Peter W. et FRIEDMAN, Allan. Cybersecurity: What everyone needs to know. oupusa, 2014.*
- *University of London. Cyber Security Fundamentals. https://www.coursera.org/learn/cyber-security-fundamentals*
- *GOUTAM, Rajesh Kumar. Cybersecurity Fundamentals: Understand the Role of Cybersecurity, Its Importance and Modern Techniques Used by Cybersecurity Professionals (English Edition). BPB Publications, 2021.*
- *SALOMAA, Arto. Public-key cryptography. 2013.*
- *BUCHMANN, Johannes. Introduction to cryptography. New York : Springer, 2004.*
- *MARIN, Gerald A. Network security basics. IEEE security & privacy, 2005, vol. 3, no 6, p. 68-72.*
- *COLE, Eric. Network security bible. John Wiley & Sons, 2011.*
- *VACCA, John R. (ed.). Network and system security. Elsevier, 2013.*
- *KARYGIANNIS, Tom et OWENS, Les. Wireless Network Security:. US Department of Commerce, Technology Administration, National Institute of Standards and Technology, 2002.*
- *HOFFMAN, Andrew. Web application security. " O'Reilly Media, Inc.", 2024.*

SEMESTRE	Intitulé de la matière	Coefficient	Crédits
S9	**Modern Networking**	**3**	**5**

VHS	Cours	Travaux Dirigés	Travaux Pratiques

Etablisement :
*Intitulé : **A**dvanced **T**echnologies in **T**elecommunications* *Année universitaire :*

67h30	1h30	1h30	1h30

Prérequis:

- Basic understanding of networking concepts (e.g., TCP/IP, routing, switching).
- Familiarity with Linux command line and basic scripting (e.g., Bash, Python).

Objectifs:

This course covers modern networking technologies such as SDN, SD-WAN, and network automation, enabling students to design, deploy, and manage advanced networking solutions. Preparing students for the evolving landscape of network architecture and services.

Contenu de l'enseignement :

Chapter1: Introduction to Modern Networking Technologies

1. Overview of traditional networking challenges
2. Definition of software-defined networking (SDN) and software-defined wide area networking (SD-WAN)
3. Introduction to network programmability and automation
4. Benefits of these technologies for enterprise networks
5. Brief history of SDN and SD-WAN development

Chapter 2: Network Virtualization: A Foundation for Modern Networking

1. Virtualization: A General concept
2. Types of virtualizations (server, storage, network)
3. Network Function Virtualization (NFV)
4. Concept of NFV and its relationship with SDN
5. Use Cases of andapplications NFV (MNF, Network slicing, …)

Chapter 3: Fundamentals of Software-Defined Networking (SDN)

1. Core concepts and benefits of SDN (separation of control and data plane, programmability)
2. SDN architecture (controllers, switches, OpenFlow protocol)
3. Use cases andapplications of SDN (data center automation, Mobile Edge Computing,…)

Chapter 4: Advanced Concepts in SDN Architecture

1. SDN controller types and functions
2. Southbound interfaces (OpenFlow, gNOI, P4)
3. Northbound APIs (NetConf, RESTCONF, gNMI)
4. Application programming interface (API)-driven networking

Chapter 5: Exploring Software-Defined Wide Area Networking (SD-WAN)

1. Traditional WAN vs SD-WAN comparison
2. Key components of SD-WAN solutions
3. SD-WAN deployment models
4. Security considerations in SD-WAN implementations

5. Real-world examples of successful SD-WAN deployments

Chapter 6: Network Automation Basics

1. Benefits and challenges of network automation
2. Python for network automation (libraries like Netmiko, Paramiko)
3. Configuration management systems (Ansible, Puppet, Chef, SaltStack)
4. Orchestration platforms (Ansible Tower, Red Hat Ansible Automation Platform, etc.)
5. Continuous integration and continuous delivery (CI/CD) pipelines for network infrastructure
6. Integrating automation with SDN and SD-WAN solutions
7. Practical Applications of Network Automation

Chapter 7: Emerging trends in Networking

1. Intent-based networking (IBN) and its role in network automation
2. Network Function Virtualization Orchestration (NFVO)
3. AI applications in network management and operations.

Travaux pratiques:

Lab1: Set up a basic SDN topology using RYU, OpenDaylight or FloodLight controllers and Open vSwitch switches.

Lab2: Exploring Southbound and Northbound APIs to program the SDN controller from external applications.

Lab3: Deployment and configuration of a virtual SD-WAN environment using EVE-NG and CISCO SD-WAN.

Lab4: Implementing basic Python scripts to automate network configuration tasks (ex. changing passwords, managing VLANs, backing up configurations)

Lab5: Utilizing Ansible to automate network device configuration changes.

Modalités d'évaluation :

Interrogation, devoir surveillé, travaux pratiques, examen final.

Références bibliographiques :

- *GORANSSON, Paul, BLACK, Chuck, et CULVER, Timothy. Software defined networks: a comprehensive approach. Morgan Kaufmann, 2016.*
- *MORREALE, Patricia A. et ANDERSON, James M. Software defined networking: Design and deployment. CRC Press, 2014.*
- *SDN Learning Resources. https://opennetworking.org/sdn-resources/sdn-learning-resources/*
- *GOOLEY, Jason, YANCH, Dana, SCHUEMANN, Dustin, et al. Cisco software-defined wide area networks: designing, Deploying and Securing Your Next Generation WAN with Cisco SD-WAN. Cisco Press, 2020.*
- *EDELMAN, Jason, LOWE, Scott S., et OSWALT, Matt. Network Programmability and Automation: Skills for the Next-Generation Network Engineer. " O'Reilly Media, Inc.", 2018.*

SEMESTRE	Intitulé de la matière	Coefficient	Crédits
S9	**Cloud and Edge Computing**	**2**	**3**

VHS	Cours	Travaux Dirigés	Travaux Pratiques

45h00	1h30	-	1h30

Prérequis:

Basic understanding of computer networks and operating systems, Familiarity with programming concepts, Proficiency in using basic computer applications and tools.

Objectifs:

This course offers a comprehensive overview of cloud and edge computing, covering service models, virtualization, major platforms, edge architectures, and security. Through theory, labs, and case studies, students will learn to design, deploy, and manage these solutions effectively.

Contenu de l'enseignement :

Chapter 1 : Introduction to Cloud Computing

1. Overview of cloud computing
2. Cloud service models (IaaS, PaaS, SaaS)
3. Cloud deploymentmodels (public, private, hybrid, multi-cloud)

Chapter 2 : Cloud Technologies and Platforms

1. Virtualization in cloud computing
2. Cloud storage and databases
3. Cloud networking concepts
4. Cloud Providers (OpenStack, AWS, Azure, GCP)

Chapter 3 : Edge Computing Fundamentals

1. Introduction to edge computing
2. Edge computing vs cloud computing
3. Edge computing architectures
4. Edge Computing Devices(e.g., sensors, gateways, edge servers)
5. Edge Computing Applications

- Edge computing for IoT
- Edge Computing to support User Applications (5G-Slicing, self-driving cars and more)
- Edge computing in various industries (e.g., manufacturing, healthcare)

Chapiter 4 : Security and Privacy in Cloud and Edge

1. Security Challenges in Cloud Computing
2. Security Challenges in Edge Computing
3. Data security and privacy Considerations
4. Best Practices

Travaux pratiques :

Lab 1: Build a private cloud environment using OpenStack
Lab 2: Simulate an IoT scenario (using Raspberry, sensors) and explore edge computing principles.
Lab 3: Deploy edge computing application, and demonstrate communication between edge devices and the cloud.
Lab 4: Analysis of edge application performance.

Modalités d'évaluation :
Interrogation, devoir surveillé, travaux pratiques, examen final.

Références bibliographiques :

- *VELTE, Anthony T. Velte Toby J. et ELSENPETER, Ph D. Robert. Cloud computing. 2010.*
- *OMETOV, Aleksandr, MOLUA, Oliver Liombe, KOMAROV, Mikhail, et al. A survey of security in cloud, edge, and fog computing. Sensors, 2022, vol. 22, no 3, p. 927.*
- *AL-TURJMAN, Fadi, JAMES, et AL-TURJMAN. Edge computing. Cham: Springer International Publishing, 2019.*
- *Openstack.* https://www.openstack.org/

SEMESTRE	Intitulé de la matière	Coefficient	Crédits
S9	**Development and Programming of IoT Systems**	**2**	**3**

VHS	Cours	Travaux Dirigés	Travaux Pratiques
45h00	1h30	-	1h30

Prérequis:

- Avoir réussi le module " IoT Networks"
- Connaissances en programmation (Python ou JavaScript)
- Connaissances de base en électronique et systèmes embarqués

Objectifs:

- Développer des applications IoT complètes, de la conception matérielle au déploiement sur le terrain.
- Maîtriser les plateformes de développement et les outils de programmation spécifiques à l'IoT.
- Acquérir des compétences en collecte, traitement et analyse des données issues des capteurs IoT.
- Comprendre les bonnes pratiques de développement et de déploiement sécurisés des systèmes IoT.

Contenu de l'enseignement :

Chapiter 1: Introduction to IoT Systems Development

1.1 Programming paradigms for IoT (event-driven, data-oriented)
1.2 Introduction to IoT development platforms (Arduino, Raspberry Pi, etc.)
1.3 Introduction to development and debugging tools specific to IoT

Chapiter 2: Embedded Programming for IoT Systems

2.1 Programming languages for IoT embedded systems (MicroPython, C, C++)
2.2 Interfacing with sensors and actuators
2.3 Programming network communication (MQTT, CoAP, etc.)
2.4 Power and energy management

Chapiter 3: IoT Application Security

3.1 Vulnerabilities and attacks specific to IoT applications
3.2 Code and communication security techniques
3.3 Certificate and authentication management
3.4 Secure development best practices for IoT

Chapiter 4: Deployment and Management of IoT Systems

4.1 Large-scale deployment strategies
4.2 Updating and maintaining deployed systems
4.3 Monitoring and diagnosing problems
4.4 Integration with existing information systems

Travaux pratiques :

Lab 1: Development of a complete IoT application with Arduino or Raspberry Pi: Data collection
Lab 2: Development of a complete IoT application with Arduino or Raspberry Pi: Data processing and visualization
Lab 3: Implementation of security in an IoT application
Lab 4: Deployment of an IoT application on a cloud platform
Lab 5: Analysis of data from IoT sensors and development of a dashboard

Modalités d'évaluation :
Interrogation, devoir surveillé, travaux pratiques, examen final.

Références bibliographiques :

- *Buyya, R., &Dastjerdi, A. V. (2016). Internet of things: Architecture and design principles. Elsevier.*
- *Gay, D. (2020). Hands-on Internet of things with Python. Packt Publishing.*
- *Prototyping Lab. (2015). Building Arduino projects for the Internet of Things: Experiment with sensors, actuators, and cloud applications. Apress.*
- *Kahn, N. D. (2017). Embedded systems design with C++: A practical introduction. Apress.*
- *Crickard, P. (2018). NoSQL databases: A beginner's guide. Apress.*

SEMESTRE	Intitulé de la matière	Coefficient	Crédits
S9	**Project:IA, IoT, Wireless Com, Security**	**2**	**3**

VHS	Cours	Travaux Dirigés	Travaux Pratiques
45h00	-	-	3h00

Prérequis: Basic understanding of artificial intelligence (AI), Internet of Things (IoT), wireless communication principles, and cybersecurity concepts.

Objectifs: Students will design & execute projects merging AI, IoT, wireless communication, & security. They'll analyze IoT data with AI, integrate sensor data, wireless comms & cloud services for IoT apps. Implementingwirelessprotocols&security to safeguard IoT systems& data.

Contenu de l'enseignement :

Etablisement :
*Intitulé : **A**dvanced **T**echnologies in **T**elecommunications* *Année universitaire :*

The course will be delivered through a project-based approach, with students working in teams to conceptualize, plan, execute, and evaluate projects under the guidance of instructors and mentors. Practical workshops, technical demonstrations, and guest lectures will supplement the project work to provide additional insights and guidance.
The course can cover the following project themes and topics but not only:

1. AI-powered IoT Applications: Design and implementation of IoT applications leveraging AI algorithms for data analysis, prediction, and decision-making.
2. Wireless Sensor Networks: Deployment of wireless sensor networks for data collection, monitoring, and control in IoT systems.
3. Security in IoT Systems: Implementation of security mechanisms such as encryption, authentication, and access control to protect IoT devices and data.
4. Real-world Applications: Application of AI, IoT, wireless communication, and security concepts to address specific challenges in domains such as smart cities, healthcare, agriculture, and industrial automation.
5. Developing an AI-powered smart home system for energy management, utilizing IoT sensors for data collection and AI algorithms for optimization.
6. Integrating IoT devices with a cloud platform to create a remote patient monitoring system for healthcare, ensuring secure data transmission and analysis.

Modalités d'évaluation : Travaux pratiques, examen final.

Références bibliographiques :

- *"Internet of Things: Principles and Paradigms" by Rajkumar Buyya, Amir Vahid Dastjerdi.*
- *"Artificial Intelligence: A Modern Approach" by Stuart Russell et Peter Norvig.*
- *"Wireless Communications & Networks" by William Stallings.*
- *"Cybersecurity and Cyberwar: What Everyone Needs to Know" by P.W. Singer et Allan Friedman.*
- *"A Survey on Internet of Things: Architecture, Enabling Technologies, Security and Privacy, and Applications" by Jayavardhana Gubbi et al. (IEEE Communications Surveys & Tutorials, 2013).*
- *"Artificial Intelligence in Internet of Things: Architectures, Algorithms, and Applications" by Anand Paul et al. (Studies in Computational Intelligence, 2019).*

SEMESTRE	Intitulé de la matière		Coefficient	Crédits
S9	**Literature Review and Thesis Design**		**1**	**1**
VHS	**Cours**	**Travaux Dirigés**	**Travaux Pratiques**	
22h30	1h30	-	-	

Objectifs de l'enseignement :
Donner à l'étudiant les outils nécessaires afin de rechercher l'information utile pour mieux l'exploiter dans son projet de fin d'études. L'aider à franchir les différentes étapes menant à la rédaction d'un document scientifique. Lui signifier l'importance de la communication et lui apprendre à présenter de manière rigoureuse et pédagogique le travail effectué.

Connaissances préalables recommandées :
Méthodologie de la rédaction, Méthodologie de la présentation.

Contenu de la matière:

Partie I- : Recherche documentaire :

Chapitre I-1 : Définition du sujet (02 Semaines)

- Intitulé du sujet
- Liste des mots clés concernant le sujet
- Rassembler l'information de base (acquisition du vocabulaire spécialisé, signification des termes, définition linguistique)
- Les informations recherchées
- Faire le point sur ses connaissances dans le domaine

Chapitre I-2 : Sélectionner les sources d'information (02 Semaines)

- Type de documents (Livres, Thèses, Mémoires, Articles de périodiques, Actes de colloques, Documents audiovisuels…)
- Type de ressources (Bibliothèques, Internet…)
- Evaluer la qualité et la pertinence des sources d'information

Chapitre I-3 : Localiser les documents (01 Semaine)

- Les techniques de recherche
- Les opérateurs de recherche

Chapitre I-4 : Traiter l'information (02 Semaines)

- Organisation du travail
- Les questions de départ
- Synthèse des documents retenus
- Liens entre différentes parties
- Plan final de la recherche documentaire

Chapitre I-5 : Présentation de la bibliographie (01 Semaine)

- Les systèmes de présentation d'une bibliographie (Le système Harvard, Le système Vancouver, Le système mixte…)
- Présentation des documents.
- Citation des sources

Partie II : Conception de mémoire

Chapitre II-1 : Plan et étapes du mémoire (02 Semaines)

- Cerner et délimiter le sujet (Résumé)
- Problématique et objectifs du mémoire
- Les autres sections utiles (Les remerciements, La table des abréviations…)
- L'introduction (*La rédaction de l'introduction en dernier lieu)*
- État de la littérature spécialisée
- Formulation des hypothèses
- Méthodologie
- Résultats
- Discussion
- Recommandations
- Conclusion et perspectives
- La table des matières
- La bibliographie
- Les annexes

Chapitre II- 2 : Techniques et normes de rédaction (02 Semaines)

- La mise en forme. Numérotation des chapitres, des figures et des tableaux.
- La page de garde
- La typographie et la ponctuation
- La rédaction. La langue scientifique : style, grammaire, syntaxe.
- L'orthographe. Amélioration de la compétence linguistique générale sur le plan de la compréhension et de l'expression.
- Sauvegarder, sécuriser, archiver ses données.

Chapitre II-3 : Atelier : Etude critique d'un manuscrit **(01 Semaine)**

Chapitre II-4 : Exposés oraux et soutenances **(01 Semaine)**

- Comment présenter un Poster
- Comment présenter une communication orale.
- Soutenance d'un mémoire

Chapitre II-5 : Comment éviter le plagiat ? **(01 Semaine)**

(Formules, phrases, illustrations, graphiques, données, statistiques,...)

- La citation
- La paraphrase
- Indiquer la référence bibliographique complète

Mode d'évaluation : Examen : 100%

Références bibliographiques :

1. *M. Griselin et al., Guide de la communication écrite, 2e édition, Dunod, 1999.*
2. *J.L. Lebrun, Guide pratique de rédaction scientifique : comment écrire pour le lecteur scientifique international, Les Ulis, EDP Sciences, 2007.*
3. *A. Mallender Tanner, ABC de la rédaction technique : modes d'emploi, notices d'utilisation, aides en ligne, Dunod, 2002.*
4. *M. Greuter, Bien rédiger son mémoire ou son rapport de stage, L'Etudiant, 2007.*

SEMESTRE	Intitulé de la matière		Coefficient	Crédits	Code
S 9	Reverse Engineering		2	2	
VHS	**Cours**	**Travaux dirigés**	**Travaux Pratiques**		
45h00	1h30	1h30 -Atelier			

Objectifs de l'enseignement

- Comprendre les principes et les objectifs du Reverse Engineering (RE) dans le domaine des sciences et de technologie (ST),
- S'initier aux outils et aux méthodes du RE dans la spécialité concernée.
- Appréhender la valeur et l'éthique des principes du RE dans le design, la fabrication et l'assurance qualitéde produits,
- Encourager la pensée critique, la curiosité technique, l'ingénierie inverse raisonnée etl'innovation,
- Apprendre à analyser, documenter et modéliser un système existant sans documentation initiale.

Compétences visées

- Décomposer et analyser un système existant,
- Reproduire fidèlementun schéma technique ou un modèle 3D à partir d'un produit existant,
- Appliquer des outils de diagnostic et de simulation,

- Travailler en groupe sur un projet exploratoire,
- Identifier les limites juridiques de la rétroconception

Pré requis –Connaissances fondamentales dans la spécialité.

Contenu de la matière

1. Introduction à la Réverse Engineering

- Historique, enjeux légaux et éthiques du RE,
- Définitions et champs d'application : Approches (matériels, logiciels, procédés…)
- Domaines : maintenance, re-fabrication, cyber sécurité, veille concurrentielle

2. Méthodologie générale

- Analyse d'un système "boîte noire" (black box)
- Décomposition fonctionnelle
- Diagrammes de blocs, entrées/sorties, flux d'énergie ou d'information

3. Reverse engineering matériel

- Dispositif Electrique –Carte Electronique : inspection visuelle, repérage de composants
- Utilisation d'outils : multimètre, oscilloscope, analyseur logique
- Reconnaissance de schémas électriques
- Reconstitution de schémas sous KiCad / Fritzing /Proteus/**EPLAN Electric P8/** QElectroTech

4. Reverse engineering logiciel

- Analyse statique de binaires (ex : .exe, .hex)
- Décompilation, désassemblage (introduction à Ghidra, IDA Free, ou Hopper)
- Observation de comportements : sniffing, monitoring (ex : Wireshark)
- Cas des microcontrôleurs : lecture mémoire flash, extraction firmware

5. Reverse engineering mécanique

- Numérisation 3D : scanner, mesures manuelles
- Reproduction de modèles CAO à partir de pièces existantes
- Logiciels utilisés : SolidWorks, Fusion360

6. Sécurité et détection d'intrusion

- Reverse engineering dans la cybersécurité : détection de malware, vulnérabilités
- Signature de logiciels, protections contre le RE (obfuscation, chiffrement)

7. Cas d'études réels

- Analyse d'un produit obsolète ou inconnu (souris, alimentation, module Bluetooth, etc.)
- Exemple de rétroconception de pièce mécanique ou système simple (ventilateur, boîtier)

Exemples de TP (base les 4 Génies)

- **Génie Electrique**

– Rétro-ingénierie d'un dispositif électrique sans schéma
– Exemple: Relais temporisé, Armoire Electrique, Variateur de vitesse, Machine Electrique, Système d'automatisation.
– Objectifs : identifier le fonctionnement, dessiner le schéma, proposer une variante améliorée.
– Identification de composants (IC, transistors, résistances, condensateurs, etc.).
– Utilisation d'outils : multimètre, oscilloscope, analyseur logique.
– Lecture et extraction de firmware depuis un microcontrôleur.

- Introduction à la détection de contrefaçons électroniques.

- **Génie Mécanique :**
- Rétro-ingénierie d'un mécanisme simple
- Exemples : pompe manuelle, clé dynamométrique, mini-presse.
- Démontage mécanique d'un système (pompe, engrenage, vérin…).
- Mesures et reconstruction de plans ou modèles 3D avec logiciel CAO (SolidWorks, Fusion360).
- Identification de matériaux et modes de fabrication.
- Simulation fonctionnelle à partir du modèle recréé.

- **Génie Civil :**
- Analyse d'ouvrages existants sans plans (murs, dalles, structures…).
- Exemples : escalier métallique, appui de fenêtre, coffrage)
- Étude et rétroconception d'un élément de structure existant
- Identification des matériaux, des assemblages et des contraintes.
- Modélisation de l'ouvrage via Revit, AutoCAD ou SketchUp.
- Étude de réhabilitation ou reproduction d'éléments structurels anciens.

- **Génie des Procédés**
- Rétroconception d'un module de laboratoire
- Exemples : instruments, distillation, filtration, échangeur, réacteur simples…
- Analyse de systèmes industriels existants (colonne de distillation, échangeur, réacteur…).
- Reconstitution des schémas PFD et PID à partir de l'observation d'une installation.
- Identification des capteurs, actionneurs, organes de commande.
- Étude de flux de matière/énergie dans un procédé.

Mode d'évaluation :

- TP techniques
- Mini-projet de rétro-ingénierie (rapport + soutenance)
- Examen final (QCM + étude de cas)
- Examen : 60% et CC TP : 40%

Références bibliographiques :

- Reverse Engineering for Beginners – Dennis Yurichev (gratuity en ligne)
- The IDA Pro Book – Chris Eagle (logiciels)
- Practical Reverse Engineering – Bruce Dang
- Documentation :
  - https://ghidra-sre.org
  - https://www.kicad.org
  - https://www.autodesk.com/products/fusion-360