AALBORG UNIVERSITET

STUDIEORDNING FOR KANDIDATUDDANNELSEN I KOMMUNIKATIONSTEKNOLOGI, 2020

CIVILINGENIØR
AALBORG

MODULER SOM INDGÅR I STUDIEORDNINGEN

INDHOLDSFORTEGNELSE

COMMUNICATION SYSTEMS

2020/2021

CONTENT, PROGRESS AND PEDAGOGY OF THE MODULE

LEARNING OBJECTIVES

KNOWLEDGE

Must have knowledge about:

- The impact of various factors on communication system behavior
- The block level description of a full communication system and the corresponding procedures required for its operation
- Communication protocols and OSI model
- At least one of the following aspects:
  - Link budget establishment for a communication system
  - Modern techniques for wireless radio transmission
  - Distribution, storage and processing of data in a distributed system
  - Real-time, performance, safety, robustness, security or mobility aspects
- Must understand the scientific communication processes related to conference presentations and related to publishing in peer-reviewed scientfic journals.
- Must know how to organize a scientific publication

SKILLS

Must be able to:

- Design, implement and analyze a solution to a practically occurring communication problem
- Establish a communication system chain
- Perform suitable test of implemented application to verify its consistency with established specifications
- Can explain the process of and criteria for peer reviewed scinetific communications
- Can write a paper for a scientific conference/journal
- Can prepare and give an oral and poster presentation for a scientific conference

COMPETENCES

Must have the ability to:

- Make a basic design, test and verification of a communication problem
- Read and understand selected scientific literature and next apply the theories, methods, and/or tools in order to solve a selected problem
- Present the problem, the suggested solution(s), experiments and simulation results, as well as the overall conclusion in terms of a scientific paper and a poster
- Present orally the main contribution and conclusion from the work in terms of a 15 minutes conference presentation
- Work according to a scientific method and present results in the form of a scientific article and at a seminar/scientific conference
- Formulate and explain scientific hypotheses and results achieved through scientific work
- Analyze results and draw conclusions on a scientific basis
- Are able to judge and prioritize the validity of various of scientific information
- Can apply internationally recognized principles for acknowledging and citing work of others properly

TYPE OF INSTRUCTION

Types of instruction are listed in §17; Structure and contents of the programme.

EXAM

EXAMS

Name of exam	Communication Systems
Type of exam	Oral exam based on a project The examination is based on questions that take their starting points in the written documentation for the project module.
ECTS	15
Assessment	7-point grading scale
Type of grading	Internal examination
Criteria of assessment	The criteria of assessment are stated in the Examination Policies and Procedures

FACTS ABOUT THE MODULE

Danish title	Kommunikationssystemer
Module code	ESNCTK1P2
Module type	Project
Duration	1 semester
Semester	Autumn
ECTS	15
Language of instruction	English
Location of the lecture	Campus Aalborg
Responsible for the module	Tatiana Kozlova Madsen

ORGANISATION

Study Board	Study Board of Electronics and IT
Department	Department of Electronic Systems
Faculty	Technical Faculty of IT and Design

STOCHASTIC PROCESSES

2020/2021

PREREQUISITE/RECOMMENDED PREREQUISITE FOR PARTICIPATION IN THE MODULE

The module builds on knowledge obtained in the modules Probability and statistics, Linear algebra and Programming.

CONTENT, PROGRESS AND PEDAGOGY OF THE MODULE

LEARNING OBJECTIVES

KNOWLEDGE

- Have knowledge about the theoretical framework in which stochastic processes are defined.
- Be able to understand the properties of the stochastic processes introduced in the course, such as wide-sense stationary (WSS) processes, Auto Regressive Moving Average (ARMA) processes, Markov models, and Poisson point processes.
- Be able to understand how WSS processes are transformed by linear time-invariant systems.
- Be able to understand the theoretical context around the introduced estimation and detection methods ((non-parametric and parametric) spectral estimation, Linear Minimum Mean Square Error (LMMSE) estimation, Wiener filter, Kalman filter, detection of signals, ARMA estimation, etc.)

SKILLS

- Be able to apply the stochastic processes taught in the course to model real random mechanisms occurring in engineering problems.
- Be able to simulate stochastic processes using a standard programming language.
- Be able to apply the taught estimation and detection methods to solve engineering problems dealing with random mechanisms.
- Be able to evaluate the performances of the introduced estimation and detection methods.

COMPETENCES

- Have the appropriate “engineering” intuition of the basic concepts and results related to stochastic processes that allow – for a particular engineering problem involving randomness – to design an appropriate model, derive solutions, assess the performance of these solutions, and possibly modify the model, and all subsequent analysis steps, if necessary.

TYPE OF INSTRUCTION

As described in § 17.

EXAM

EXAMS

Name of exam	Stochastic Processes
Type of exam	Written or oral exam
ECTS	5
Assessment	7-point grading scale
Type of grading	Internal examination

Criteria of assessment	The criteria of assessment are stated in the Examination Policies and Procedures

FACTS ABOUT THE MODULE

Danish title	Stokastiske processer
Module code	ESNCAK1K1F
Module type	Course
Duration	1 semester
Semester	Autumn
ECTS	5
Language of instruction	English
Empty-place Scheme	Yes
Location of the lecture	Campus Aalborg
Responsible for the module	Ove Kjeld Andersen

ORGANISATION

Study Board	Study Board of Electronics and IT
Department	Department of Electronic Systems
Faculty	Technical Faculty of IT and Design

WIRELESS COMMUNICATION SYSTEMS AND NETWORKS

2020/2021

CONTENT, PROGRESS AND PEDAGOGY OF THE MODULE

LEARNING OBJECTIVES

KNOWLEDGE

The students must have insight in:

- Communication over shared wireless medium
- Layering in communication systems
- Baseband communication
- Information theoretic representation of wireless communication systems
- Waveforms and frequency
- Propagation, antennas and full receiver structure
- Cellular structure and spatial reuse
- General network models and architectures
- Routing and transport protocols; principles of congestion control

SKILLS

The students must have understanding of:

- Different multiple access protocols for wireless communication systems
- Separation of functionalities in different layers in a communication system
- Reliability of end-to-end data delivery and Quality of Service
- Feasibility evaluation of routing and transport strategies based on system properties and requirements
- Selection of relevant metrics to establish and estimate Quality of Service performance
- How modulation is used for transmitting data over a wireless channel and how the performance is impacted by interference and noise
- How wireless signals can be represented mathematically using complex baseband notation as well as information and communication theoretic models.
- How wireless data transmissions are mapped onto time and frequency resources
- Propagation phenomena such as path loss, multipath and shadowing and corresponding models as well as their impact on performance
- Implications of using multiple antennas in a wireless communication system

COMPETENCES

The students must be able to

- design an abstract communication system chain and protocol stack, and justify the design choices in relation to the intended use case
- use relevant abstractions and models from information and communication theory to model the constituent parts of a communication system and quantify the expected performance of different communication system blocks

TYPE OF INSTRUCTION

Types of instruction are listed in §17; Structure and contents of the programme.

EXAM

EXAMS

Name of exam	Wireless Communication Systems and Networks
Type of exam	Written or oral exam
ECTS	5
Assessment	Passed/Not Passed
Type of grading	Internal examination
Criteria of assessment	The criteria of assessment are stated in the Examination Policies and Procedures

FACTS ABOUT THE MODULE

Danish title	Trådløse kommunikationssystemer og netværk
Module code	ESNCTK1K1
Module type	Course
Duration	1 semester
Semester	Autumn
ECTS	5
Language of instruction	English
Location of the lecture	Campus Aalborg
Responsible for the module	Tatiana Kozlova Madsen

ORGANISATION

Study Board	Study Board of Electronics and IT
Department	Department of Electronic Systems
Faculty	Technical Faculty of IT and Design

OPTIMIZATION METHODS

2020/2021

CONTENT, PROGRESS AND PEDAGOGY OF THE MODULE

LEARNING OBJECTIVES

KNOWLEDGE

- Must have knowledge about different classes of optimization problems.
- Must have knowledge about objective function, global/local minima, constrained/unconstrained, convex/non-convex functions and sets.
- Must have knowledge about the consequences of dimensionality.
- Must have knowledge about gradient and optimal gradient methods.
- Must have knowledge about Newton and interior-point methods for constrained optimization.
- Must have knowledge about line search methods and stop criteria.
- Must have knowledge about tools for non-linear optimization.
- Must have knowledge about methods for solving combinatorial optimization problems, such as Simulated Annealing (SA), Genetic Algorithms (GA), ant colony optimization, and Integer Linear Programming (ILP).

SKILLS

- Must be able to identify problem classes.
- Must be able to apply optimization methods in order to design and implement algorithms for continuous and discrete optimization.
- Must be able to evaluate the performance of optimization algorithms.
- Must be able to transform optimization problems to standard form and use off-the-shell optimization software.
- Must be able to evaluate and understand numerical aspects of optimization algorithms.

COMPETENCES

- Must have an understanding of how to formulate optimization problems in signal processing.
- Must have competencies in applying optimization in signal processing applications.

TYPE OF INSTRUCTION

As described in § 17.

EXAM

EXAMS

Name of exam	Optimization Methods
Type of exam	Written or oral exam
ECTS	5
Assessment	Passed/Not Passed
Type of grading	Internal examination
Criteria of assessment	The criteria of assessment are stated in the Examination Policies and Procedures

FACTS ABOUT THE MODULE

Danish title	Optimeringsmetoder
Module code	ESNSPAK1K2
Module type	Course
Duration	1 semester
Semester	Autumn
ECTS	5
Language of instruction	English
Location of the lecture	Campus Aalborg
Responsible for the module	Ove Kjeld Andersen

ORGANISATION

Study Board	Study Board of Electronics and IT
Department	Department of Electronic Systems
Faculty	Technical Faculty of IT and Design

ROBUST AND HIGH PERFORMANCE COMMUNICATION SYSTEMS

2020/2021

CONTENT, PROGRESS AND PEDAGOGY OF THE MODULE

LEARNING OBJECTIVES

KNOWLEDGE

- Major performance measures in communication systems
- Major factors that influence the performance of a communication system
- Techniques for increasing the resilience towards errors in the considered type of communication system
- At least one of the following aspects:
    - Digital communication of analog or digital data over a stochastic fading channel. A basic wireless communication system and identify the individual blocks and their interaction. Thus, comprising the ends of the communication links, the transmission technique, the access technology as well as the fading channel. The interaction of multiple communication links which are jointly considered to optimize system performance. Performance enhancing properties of multi antenna system or other technology, in a wireless communication system, with focus on the lower layers of the communication chain. Channel characterization and processing algorithms to exploit multi link radio propagation mechanisms of multiple antenna systems.
- or
    - System design methodologies within distributed systems in general. How choices of architecture, topology and technology influence the performance, robustness and security aspects of a distributed system. Methods and tools to achieve fault tolerant, secure and efficient operation of a distributed system. Protocol design to support distributed mode of operation in a communication network. Data access and data delivery in a scalable manner. Data management issues in complex networks

SKILLS

- conduct synthesis of theories, methods and techniques used for at least one of the following:
    - robust communication
    - distribution, storage and processing of data in a distributed system
    - secure communication
    - Capacity, energy optimizations etc
- apply relevant theories, methods and techniques to the chosen system to ensure that at least one of the following requirements are satisfied:
- performance, robustness, reliability or security requirements, timing requirements and/ or reliability requirements in connection with distribution, storage or processing of data
- deal with at least one of the following:
    - Compare and evaluate the stochastically varying links, apply and assess stabilization methods to compensate for these variations.
    - Evaluate the space and frequency dispersive behavior of the channel.
    - Must be able to evaluate and select among different multi antenna techniques for channel stabilization and capacity enhancement.
    - Evaluate the impact on system performance, by joint treatment of links in a multi-user/multi- network scenario – or other interaction mechanisms
    - Design protocols and algorithms that are able to support e.g. disruption tolerant networking, multi-hop communication in sensor networks, embedded systems, real-time and multimedia systems, content distribution networks, peer-to-peer systems, large scale distributed systems, storage and file systems, autonomic computing, network security.

COMPETENCES

- undertake the construction of a well-functioning robust communication system yielding high performance and efficiency.
- Communicate the project work in sound scientific and academic form
- Contribute successfully to team work within the problem area and make a common presentation of the project work

TYPE OF INSTRUCTION

Types of instruction are listed at the start of §17; Structure and contents of the programme.

EXAM

PREREQUISITE FOR ENROLLMENT FOR THE EXAM

- An approved PBL competency profile is a prerequisite for participation in the project exam

EXAMS

Name of exam	Robust and High Performance Communication Systems
Type of exam	Oral exam based on a project
ECTS	20
Assessment	7-point grading scale
Type of grading	External examination
Criteria of assessment	The criteria of assessment are stated in the Examination Policies and Procedures

FACTS ABOUT THE MODULE

Danish title	Robuste og højt ydende kommunikationssystemer
Module code	ESNCTK2P1F
Module type	Project
Duration	1 semester
Semester	Spring
ECTS	20
Language of instruction	English
Empty-place Scheme	Yes
Location of the lecture	Campus Aalborg
Responsible for the module	Tatiana Kozlova Madsen

ORGANISATION

Study Board	Study Board of Electronics and IT
Department	Department of Electronic Systems
Faculty	Technical Faculty of IT and Design

DYNAMIC CHANNELS AND ADVANCED SIGNAL PROCESSING

2020/2021

PREREQUISITE/RECOMMENDED PREREQUISITE FOR PARTICIPATION IN THE MODULE

The module builds on knowledge obtained the module "Stochastic Processes".

CONTENT, PROGRESS AND PEDAGOGY OF THE MODULE

LEARNING OBJECTIVES

KNOWLEDGE

The students must have insight in:

- Dynamic channels:
  - Power vs protection margins
  - Dynamic radio channel characterization
    - Short term scattering descriptions for single and multiple links
    - Channel hardening/Diversity
  - Item the interaction of multiple communication links which are jointly considered to optimize system performance
- Advanced signal processing
  - Channel characterization and processing algorithms to exploit multi link radio propagation mechanisms of multiple antenna systems, such as
    - Space and time processing
    - Spatial data multiplexing and space-time coding
    - Time reversal techniques

SKILLS

The students must have understanding of:

- Establish a link budget with account for dynamic protection margins for a given wireless communication system
- Evaluate properties of dynamic channels and apply stabilization techniques
- Evaluate the impact on system performance, by joint treatment of links in a multi-user/multi- network scenario – or other interaction mechanisms.
- Apply processing methods for time and space exploitation of the wireless radio channel.

COMPETENCES

The students must be able to

- Analyze, evaluate and model the PHY related signal impacts and manipulation options - and its relevance to a wireless communication system

TYPE OF INSTRUCTION

Types of instruction are listed in §17; Structure and contents of the programme.

EXAM

EXAMS

Name of exam	Dynamic Channels and Advanced Signal Processing
Type of exam	Written or oral exam
ECTS	5
Assessment	Passed/Not Passed
Type of grading	Internal examination
Criteria of assessment	The criteria of assessment are stated in the Examination Policies and Procedures

FACTS ABOUT THE MODULE

Danish title	Dynamiske kanaler og avanceret signalbehandling
Module code	ESNCTK2K1
Module type	Course
Duration	1 semester
Semester	Spring
ECTS	5
Language of instruction	English
Location of the lecture	Campus Aalborg
Responsible for the module	Tatiana Kozlova Madsen

ORGANISATION

Study Board	Study Board of Electronics and IT
Department	Department of Electronic Systems
Faculty	Technical Faculty of IT and Design

ANALYSIS AND DESIGN OF COMMUNICATION TECHNOLOGIES

2020/2021

PREREQUISITE/RECOMMENDED PREREQUISITE FOR PARTICIPATION IN THE MODULE

The module builds upon knowledge obtained during the 1st and 2nd semester

CONTENT, PROGRESS AND PEDAGOGY OF THE MODULE

LEARNING OBJECTIVES

KNOWLEDGE

The students must have insight in:

Specific in-depth knowledge about at least one advanced method or technology applied to wireless communications or networks. Such as:

- Methods used to model electro-magnetic properties of antennas and propagation for wireless communication, and exploit their characteristics for terminal or system performance
- Modelling (and design) of RF circuits and systems
- Modelling and performance analysis of communication protocols and networks
- Tools and methods for distributed systems management and security

SKILLS

The students must have understanding of

- basic as well as advanced methods for performance analysis in wireless communication systems and/or communication networks and/or distributed systems.
- apply tools for performance analysis of antennas and RF circuits or analysis of distributed systems and/or communication networks.

COMPETENCES

The students must be able to

- make a choice of parameters, methods and tools for the analysis or design of a problem where a communication system comprises a dominant part of the solution

TYPE OF INSTRUCTION

Types of instruction are listed in §17; Structure and contents of the programme.

EXAM

EXAMS

Name of exam	Analysis and Design of Communication Technologies
Type of exam	Oral exam based on a project
ECTS	20

Assessment	7-point grading scale
Type of grading	Internal examination
Criteria of assessment	The criteria of assessment are stated in the Examination Policies and Procedures

FACTS ABOUT THE MODULE

Danish title	Analyse og design af kommunikationsteknologier
Module code	ESNCTK3P1
Module type	Project
Duration	1 semester
Semester	Autumn
ECTS	20
Language of instruction	English
Location of the lecture	Campus Aalborg
Responsible for the module	Tatiana Kozlova Madsen

ORGANISATION

Study Board	Study Board of Electronics and IT
Department	Department of Electronic Systems
Faculty	Technical Faculty of IT and Design

ANTENNAS, PROPAGATION AND RF CIRCUITS

2020/2021

PREREQUISITE/RECOMMENDED PREREQUISITE FOR PARTICIPATION IN THE MODULE

The module builds upon knowledge obtained during the modules Wireless communication systems and networks (1st semester) and Dynamic channels (2nd semester).

CONTENT, PROGRESS AND PEDAGOGY OF THE MODULE

LEARNING OBJECTIVES

KNOWLEDGE

The students must have insight in:

- Antennas
- Requirements for antennas in a scattering radio environment
- Multi-antenna/ correlation analysis
- Antenna measurement principles
- Near field (antenna design)
    - Finite Difference Time Domain (FDTD) Method
    - Method of Moments
- Far field (propagation)
    - Ray tracing
    - Phase screen methods and diffraction
- RF circuits
    - Transceiver structures and synchronization (incl. duplexing and access aspects)
    - Non-ideal components (non-linearities, compression and intercept)
    - Noise factor
    - S-parameter description of components
    - RF/u-wave measurements of wireless communication blocks and chains

SKILLS

The students must have understanding of:

- Identify connection between antenna system and radio channel behavior
- Assess performance of antenna elements and antenna systems
- Select appropriate Electro-magnetic near and far field Simulation methodology for realistic antenna and propagation settings

- Synthesize a transceiver system on a block diagram level
- Describe the modifications that a signal undergoes through a transceiver chain or individual RF circuits
- Simulate the transmission of digital data through a full transceiver chain or individual circuits – including transmitter, lossy and noisy wireless channel, and receiver

COMPETENCES

The students must be able to:

- Apply antenna(system) and propagation conditions in new/real-world constellations for analyzing wireless communication system impact and performance optimization
- Evaluate limits of the methods and theories as applied to more general problems
- Discuss and evaluate the impact of different transceiver blocks in a communication link
- Set up a simulation model to access and evaluate the performance of (digital data) transmission over a wireless communication link

TYPE OF INSTRUCTION

Types of instruction are listed in §17; Structure and contents of the programme.

EXAM

EXAMS

Name of exam	Antennas, Propagation and RF Circuits
Type of exam	Written or oral exam
ECTS	5
Assessment	Passed/Not Passed
Type of grading	Internal examination
Criteria of assessment	The criteria of assessment are stated in the Examination Policies and Procedures

FACTS ABOUT THE MODULE

Danish title	Antenner, udbredelse og RF-kredsløb
Module code	ESNCTK3K1
Module type	Course
Duration	1 semester
Semester	Autumn
ECTS	5
Language of instruction	English
Location of the lecture	Campus Aalborg
Responsible for the module	Tatiana Kozlova Madsen

ORGANISATION

Study Board	Study Board of Electronics and IT
Department	Department of Electronic Systems
Faculty	Technical Faculty of IT and Design

ANALYSIS AND DESIGN OF COMMUNICATION TECHNOLOGIES

2020/2021

PREREQUISITE/RECOMMENDED PREREQUISITE FOR PARTICIPATION IN THE MODULE

The module builds upon knowledge obtained during the 1st and 2nd semester

CONTENT, PROGRESS AND PEDAGOGY OF THE MODULE

LEARNING OBJECTIVES

KNOWLEDGE

The students must have insight in:

Specific in-depth knowledge about at least one advanced method or technology applied to wireless communications or networks. Such as:

- Methods used to model electro-magnetic properties of antennas and propagation for wireless communication, and exploit their characteristics for terminal or system performance
- Modelling (and design) of RF circuits and systems
- Modelling and performance analysis of communication protocols and networks
- Tools and methods for distributed systems management and security

SKILLS

The students must have understanding of

- basic as well as advanced methods for performance analysis in wireless communication systems and/or communication networks and/or distributed systems.
- apply tools for performance analysis of antennas and RF circuits or analysis of distributed systems and/or communication networks.

COMPETENCES

The students must be able to

- make a choice of parameters, methods and tools for the analysis or design of a problem where a communication system comprises a dominant part of the solution

TYPE OF INSTRUCTION

Types of instruction are listed in §17; Structure and contents of the programme.

EXAM

EXAMS

Name of exam	Analysis and Design of Communication Technologies
Type of exam	Oral exam based on a project
ECTS	25

Assessment	7-point grading scale
Type of grading	Internal examination
Criteria of assessment	The criteria of assessment are stated in the Examination Policies and Procedures

FACTS ABOUT THE MODULE

Danish title	Analyse og design af kommunikationsteknologier
Module code	ESNCTK3P2
Module type	Project
Duration	1 semester
Semester	Autumn
ECTS	25
Language of instruction	English
Location of the lecture	Campus Aalborg
Responsible for the module	Tatiana Kozlova Madsen

ORGANISATION

Study Board	Study Board of Electronics and IT
Department	Department of Electronic Systems
Faculty	Technical Faculty of IT and Design

ANALYSIS AND DESIGN OF COMMUNICATION TECHNOLOGIES

2020/2021

PREREQUISITE/RECOMMENDED PREREQUISITE FOR PARTICIPATION IN THE MODULE

The module builds upon knowledge obtained during the 1st and 2nd semester

CONTENT, PROGRESS AND PEDAGOGY OF THE MODULE

LEARNING OBJECTIVES

KNOWLEDGE

The students must have insight in:

Specific in-depth knowledge about at least one advanced method or technology applied to wireless communications or networks such as:

- Methods used to model electro-magnetic properties of antennas and propagation for wireless communication, and exploit their characteristics for terminal or system performance
- Modelling (and design) of RF circuits and systems
- Modelling and performance analysis of communication protocols and networks
- Tools and methods for distributed systems management and security

SKILLS

The students must have understanding of

- basic as well as advanced methods for performance analysis in wireless communication systems and/or communication networks and/or distributed systems.
- apply tools for performance analysis of antennas and RF circuits or analysis of distributed systems and/or communication networks.

COMPETENCES

The students must be able to

- make a choice of parameters, methods and tools for the analysis or design of a problem where a communication system comprises a dominant part of the solution

TYPE OF INSTRUCTION

Types of instruction are listed in §17; Structure and contents of the programme.

EXAM

EXAMS

Name of exam	Analysis and Design of Communication Technologies
Type of exam	Oral exam based on a project
ECTS	30

Assessment	7-point grading scale
Type of grading	Internal examination
Criteria of assessment	The criteria of assessment are stated in the Examination Policies and Procedures

FACTS ABOUT THE MODULE

Danish title	Analyse og design af kommunikationsteknologier
Module code	ESNCTK3P3
Module type	Project
Duration	1 semester
Semester	Autumn
ECTS	30
Language of instruction	English
Location of the lecture	Campus Aalborg
Responsible for the module	Tatiana Kozlova Madsen

ORGANISATION

Study Board	Study Board of Electronics and IT
Department	Department of Electronic Systems
Faculty	Technical Faculty of IT and Design

MASTER'S THESIS

2020/2021

PREREQUISITE/RECOMMENDED PREREQUISITE FOR PARTICIPATION IN THE MODULE

The master's thesis build on knowledge obtained during the 1st – 3rd Semester

CONTENT, PROGRESS AND PEDAGOGY OF THE MODULE

The master thesis can be conducted as a long master thesis. If choosing to do a long master thesis, it has to include experimental work and has to be approved by the study board. The amount of experimental work must reflect the allotted ECTS.

LEARNING OBJECTIVES

KNOWLEDGE

- have knowledge, at the highest international level of research, of at least one of the core fields of the education
- have comprehension of implications of research (research ethics)

SKILLS

- are able to reflect on a scientific basis on their knowledge,
- can argue for the relevance of the chosen problem to the education including specifically account for the core of the problem and the technical connections in which it appears
- can account for possible methods to solve the problem statements of the project, describe and assess the applicability of the chosen method including account for the chosen delimitation and the way these will influence on the results of the product
- can analyze and describe the chosen problem applying relevant theories, methods and experimental data
- are able to describe the relevant theories and methods in a way that highlights the characteristics and hereby document knowledge of the applied theories, methods, possibilities and delimitations within the relevant problem area
- have the ability to analyze and assess experimental data, including the effect the assessment method has on the validity of the results.

COMPETENCES

- are able to communicate scientific problems in writing and orally to specialist and non-specialist.
- are able to control situations that are complex, unpredictable and which require new solutions,
- are able to independently initiate and to perform collaboration within the discipline and interdisciplinary as well, and to take professional responsibility,
- are able to independently take responsibility for his or her own professional development and specialization.

TYPE OF INSTRUCTION

Problem based project oriented project work individual or in groups of 2-3 persons

EXAM

EXAMS

Name of exam	Master's Thesis
Type of exam	Master's thesis/final project

	The examination is based on questions that take their starting points in the written documentation for the project module.
ECTS	50
Assessment	7-point grading scale
Type of grading	External examination
Criteria of assessment	The criteria of assessment are stated in the Examination Policies and Procedures

FACTS ABOUT THE MODULE

Danish title	Kandidatspeciale
Module code	ESNCTK4P2
Module type	Project
Duration	1 semester
Semester	Spring
ECTS	50
Language of instruction	English
Location of the lecture	Campus Aalborg
Responsible for the module	Tatiana Kozlova Madsen

ORGANISATION

Study Board	Study Board of Electronics and IT
Department	Department of Electronic Systems
Faculty	Technical Faculty of IT and Design

MASTER'S THESIS

2020/2021

PREREQUISITE/RECOMMENDED PREREQUISITE FOR PARTICIPATION IN THE MODULE

The master's thesis build on knowledge obtained during the 1st – 3rd Semester

CONTENT, PROGRESS AND PEDAGOGY OF THE MODULE

The master thesis can be conducted as a long master thesis. If choosing to do a long master thesis, it has to include experimental work and has to be approved by the study board. The amount of experimental work must reflect the allotted ECTS.

LEARNING OBJECTIVES

KNOWLEDGE

- have knowledge, at the highest international level of research, of at least one of the core fields of the education
- have comprehension of implications of research (research ethics)

SKILLS

- are able to reflect on a scientific basis on their knowledge,
- can argue for the relevance of the chosen problem to the education including specifically account for the core of the problem and the technical connections in which it appears
- can account for possible methods to solve the problem statements of the project, describe and assess the applicability of the chosen method including account for the chosen delimitation and the way these will influence on the results of the product
- can analyze and describe the chosen problem applying relevant theories, methods and experimental data
- are able to describe the relevant theories and methods in a way that highlights the characteristics and hereby document knowledge of the applied theories, methods, possibilities and delimitations within the relevant problem area
- have the ability to analyze and assess experimental data, including the effect the assessment method has on the validity of the results.

COMPETENCES

- are able to communicate scientific problems in writing and orally to specialist and non-specialist.
- are able to control situations that are complex, unpredictable and which require new solutions,
- are able to independently initiate and to perform collaboration within the discipline and interdisciplinary as well, and to take professional responsibility,
- are able to independently take responsibility for his or her own professional development and specialization.

TYPE OF INSTRUCTION

Problem based project oriented project work individual or in groups of 2-3 persons

EXAM

EXAMS

Name of exam	Master's Thesis
Type of exam	Master's thesis/final project

	The examination is based on questions that take their starting points in the written documentation for the project module.
ECTS	30
Assessment	7-point grading scale
Type of grading	External examination
Criteria of assessment	The criteria of assessment are stated in the Examination Policies and Procedures

FACTS ABOUT THE MODULE

Danish title	Kandidatspeciale
Module code	ESNCTK4P1
Module type	Project
Duration	1 semester
Semester	Spring
ECTS	30
Language of instruction	English
Location of the lecture	Campus Aalborg
Responsible for the module	Tatiana Kozlova Madsen

ORGANISATION

Study Board	Study Board of Electronics and IT
Department	Department of Electronic Systems
Faculty	Technical Faculty of IT and Design

NUMERICAL SCIENTIFIC COMPUTING

2020/2021

CONTENT, PROGRESS AND PEDAGOGY OF THE MODULE

LEARNING OBJECTIVES

KNOWLEDGE

The students must have insight in:

- Must have knowledge about hardware and software platforms for scientific computing.
- Must have knowledge about the possible speedup by using parallelization (Amdahls law / Gustafson-Barsis' law) under different conditions.
- Must have knowledge about message and data passing in distributed computing.
- Must have knowledge about programming techniques, profiling, benchmarking, code optimization etc.
- Must have knowledge about numerical accuracy in scientific computing problems.
- Must have knowledge about what typically characterizes problem-specific scientific computing software vs. general, user-oriented commercial software
- Must have knowledge about one or more software development methods of relevance to development of scientific computing software

SKILLS

The students must have understanding of:

- Must be able to translate the covered principles regarding scientific computing and software development to practice in the programming language(s) utilized in the course
- Must be able to implement software programs to solve scientific computational problems using parallel computing.
- Must be able to implement software programs to solve scientific computational problems using distributed computing units or high-performance specialized computing units (such as GPU)
- Must be able to debug, validate, optimize, benchmark and profile developed software modules.
- Must be able to assess the performance of different hardware architectures for scientific computing problems.

COMPETENCES

The students must be able to

- The student must be able to apply the proper terminology in oral and written communication and documentation within the scientific domains of numerical scientific computing
- Must be able to assess and weigh resources spent on software development against total subsequent computing time for concrete scientific computing problems.
- Must be able to reflect on different software development methods and independently select and combine elements thereof for use in concrete scientific computing problems.
- Must be able to independently adapt and apply the covered methods and principles for complex scientific computing problems within the students' professional field

TYPE OF INSTRUCTION

Types of instruction are listed in §17; Structure and contents of the programme.

EXAM

EXAMS

Name of exam	Numerical Scientific Computing

Type of exam	Written or oral exam
ECTS	5
Assessment	Passed/Not Passed
Type of grading	Internal examination
Criteria of assessment	The criteria of assessment are stated in the Examination Policies and Procedures

FACTS ABOUT THE MODULE

Danish title	Numerisk videnskabelig beregning
Module code	ESNCTK2K3
Module type	Course
Duration	1 semester
Semester	Spring
ECTS	5
Language of instruction	English
Location of the lecture	Campus Aalborg
Responsible for the module	Tatiana Kozlova Madsen

ORGANISATION

Study Board	Study Board of Electronics and IT
Department	Department of Electronic Systems
Faculty	Technical Faculty of IT and Design

RECONFIGURABLE AND LOW ENERGY SYSTEMS

2020/2021

CONTENT, PROGRESS AND PEDAGOGY OF THE MODULE

LEARNING OBJECTIVES

KNOWLEDGE

The students must have knowledge about:

- Representation of Digital Signal Processing (DSP) algorithms
- Cost functions, models of computation and complexity
- Iteration bounds
- Pipelining and retiming
- Folding and unfolding
- Scheduling and allocation
- Data path, control path, Finite State Machine with Data path (FSMD)
- Functional unit arithmetic
- Low power design methods

SKILLS

The students must be able to:

- Apply advanced terms, concepts, and methods, in the context of time-, area-, or energy optimal/constrained mapping of DSP algorithms onto real-time HW/SW architectures.

COMPETENCES

The students must be able to:

- Apply the proper terminology in oral and written communication and documentation within the scientific domains of DSP algorithms, and application specific HW/SW architectures

TYPE OF INSTRUCTION

Types of instruction are listed in §17; Structure and contents of the programme.

EXAM

EXAMS

Name of exam	Reconfigurable and Low Energy Systems
Type of exam	Written or oral exam
ECTS	5
Assessment	Passed/Not Passed
Type of grading	Internal examination
Criteria of assessment	The criteria of assessment are stated in the Examination Policies and Procedures

FACTS ABOUT THE MODULE

Danish title	Rekonfigurerbare systemer og energi-minimale systemer
Module code	ESNCTK2K4
Module type	Course
Duration	1 semester
Semester	Spring
ECTS	5
Language of instruction	English
Empty-place Scheme	Yes
Location of the lecture	Campus Aalborg
Responsible for the module	Tatiana Kozlova Madsen

ORGANISATION

Study Board	Study Board of Electronics and IT
Department	Department of Electronic Systems
Faculty	Technical Faculty of IT and Design

MACHINE LEARNING

2020/2021

CONTENT, PROGRESS AND PEDAGOGY OF THE MODULE

The course gives a comprehensive introduction to machine learning, which is a field concerned with learning from examples and has roots in computer science, statistics and pattern recognition. The objective is realized by presenting methods and tools proven valuable and by addressing specific application problems.

LEARNING OBJECTIVES

KNOWLEDGE

- Must have knowledge about supervised learning methods including K-nearest neighbors, decision trees, linear discriminant analysis, support vector machines, and neural networks.
- Must have knowledge about unsupervised learning methods including K-means, Gaussian mixture model, hidden Markov model, EM algorithm, and principal component analysis.
- Must have knowledge about probabilistic graphical models, variational Bayesian methods, belief propagation, and mean-field approximation.
- Must have knowledge about Bayesian decision theory, bias and variance trade-off, and cross-validation.
- Must be able to understand reinforcement learning.

SKILLS

- Must be able to apply the taught methods to solve concrete engineering problems.
- Must be able to evaluate and compare the methods within a specific application problem.

COMPETENCES

- Must have competencies in analyzing a given problem and identifying appropriate machine learning methods to the problem.
- Must have competencies in understanding the strengths and weaknesses of the methods.

TYPE OF INSTRUCTION

As described in § 17.

EXAM

EXAMS

Name of exam	Machine Learning
Type of exam	Written or oral exam
ECTS	5
Assessment	Passed/Not Passed
Type of grading	Internal examination
Criteria of assessment	The criteria of assessment are stated in the Examination Policies and Procedures

FACTS ABOUT THE MODULE

Danish title	Maskinlæring

Module code	ESNSPAK3K2F
Module type	Course
Duration	1 semester
Semester	Autumn
ECTS	5
Language of instruction	English
Empty-place Scheme	Yes
Location of the lecture	Campus Aalborg
Responsible for the module	Ove Kjeld Andersen

ORGANISATION

Study Board	Study Board of Electronics and IT
Department	Department of Electronic Systems
Faculty	Technical Faculty of IT and Design

INFORMATION AND CODING THEORY

2020/2021

PREREQUISITE/RECOMMENDED PREREQUISITE FOR PARTICIPATION IN THE MODULE

The module builds upon knowledge obtained the modules "Probability Theory" and "Linear Algebra".

CONTENT, PROGRESS AND PEDAGOGY OF THE MODULE

LEARNING OBJECTIVES

KNOWLEDGE

- knowledge of information theoretical concepts such as entropy, mutual information,
- divergence, the chain rule for entropy, empirical entropy
- knowledge of lossless data compression, entropy coding, lossy data compression (rate
- distortion theory)
- knowledge of channel capacity and error-correcting codes
- knowledge of joint source-channel coding and the separation principle

SKILLS

- are able to give a theoretical description of the entropy of a signal and in practice estimate the entropy of simple signals
- are able to design efficient entropy codes for simple signals
- are able to use information inequalities to provide bounds on optimal performance of simple systems
- are able to construct error-correcting codes with good properties and parameters
- are able to decode error-correcting codes efficiently (e.g. Reed-Solomon codes)
- understand the interaction between bitrate and distortion (reconstruction error) in connection with source coding
- understand the interaction between bitrate and error probability in connection with channel coding
- are able to perform calculations in finite fields

COMPETENCES

- have a good intuition and understanding of the concept of entropy and its significance
- regarding the information within a signal
- be able to use mathematical tools to discover and investigate the fundamental
- mathematical tools that describes data transmission, data reduction and data storage

TYPE OF INSTRUCTION

Types of instruction are listed in §17; Structure and contents of the programme.

EXAM

EXAMS

Name of exam	Information and Coding Theory
Type of exam	Written or oral exam
ECTS	5
Assessment	Passed/Not Passed
Type of grading	Internal examination

Criteria of assessment	The criteria of assessment are stated in the Examination Policies and Procedures

FACTS ABOUT THE MODULE

Danish title	Information og kodningsteori
Module code	ESNCTK3K2
Module type	Course
Duration	1 semester
Semester	Autumn
ECTS	5
Language of instruction	English
Location of the lecture	Campus Aalborg
Responsible for the module	Tatiana Kozlova Madsen

ORGANISATION

Study Board	Study Board of Electronics and IT
Department	Department of Electronic Systems
Faculty	Technical Faculty of IT and Design

ARRAY AND SENSOR SIGNAL PROCESSING

2020/2021

CONTENT, PROGRESS AND PEDAGOGY OF THE MODULE

LEARNING OBJECTIVES

KNOWLEDGE

- Must have knowledge about the Cramér-Rao lower bound (CRLB) as well as (asymptotic) optimal unbiased estimators such as minimum variance unbiased estimator, maximum likelihood, and least-squares.
- Must have knowledge about 1- and 2-dimensional spectral estimation methods such as the period gram, the Yule-Walker equations, subspace-based methods (MUSIC and ESPRIT), and filter-bank methods (Capon's method and Amplitude and Phase EStimation (APES)).
- Must have knowledge about fundamental terms and methods applied for design and analysis of adaptive filter such as Steepest descent, least-mean-square (LMS), normalized LMS (NLMS), affine projections (AP), recursive least-squares (RLS), transient and steady-state performance.
- Must have knowledge about terms and methods applied for design and analysis of multi-rate signal processing systems, such as Hilbert transform, Noble identities, poly-phase decomposition, commutators, re-sampling, as well as up- and down-sampling.

SKILLS

- Must be able to compare the estimation performance of unbiased estimators by using the CRLB.
- Must be able to apply methods and algorithms for parametric and non-parametric spectral estimation on 1- and 2-dimensional signals.
- Must be able to implement fundamental adaptive filters such as the (normalized) least-mean-square filter, the affine projection filter, and the recursive least-squares filter.
- Must be able to apply fundamental methods for analysis, design, and implementation of poly-phase filters.

COMPETENCES

- Must have competencies in analyzing a given problem which in its solution requires advanced signal processing methodologies and next identify appropriate methods and algorithms to solve the problem.
- Must have competencies in understanding the strengths and weaknesses of the methods

TYPE OF INSTRUCTION

As described in § 17.

EXAM

EXAMS

Name of exam	Array and Sensor Signal Processing
Type of exam	Written or oral exam
ECTS	5
Assessment	Passed/Not Passed
Type of grading	Internal examination
Criteria of assessment	The criteria of assessment are stated in the Examination Policies and Procedures

FACTS ABOUT THE MODULE

Danish title	Array- og sensor signalbehandling
Module code	ESNSPAK3K1
Module type	Course
Duration	1 semester
Semester	Autumn
ECTS	5
Language of instruction	English
Empty-place Scheme	Yes
Location of the lecture	Campus Aalborg
Responsible for the module	Ove Kjeld Andersen

ORGANISATION

Study Board	Study Board of Electronics and IT
Department	Department of Electronic Systems
Faculty	Technical Faculty of IT and Design

DISTRIBUTED REAL TIME SYSTEMS

2020/2021

PREREQUISITE/RECOMMENDED PREREQUISITE FOR PARTICIPATION IN THE MODULE

The module builds on knowledge obtained in the courses Communication in Electronic Systems (EIT 5th Semester) or Network Technologies and Distributed Systems (ITC 5th Semester).

CONTENT, PROGRESS AND PEDAGOGY OF THE MODULE

LEARNING OBJECTIVES

KNOWLEDGE

- fieldbus technologies and concepts of communication
- global state protocols
- replication of systems for redundancy concerns
- application domains and their requirements, relevant Quality of Service parameters
- queuing theory, basic models
- synchronization issues
- reliability modeling, including safety, scalability, maintainability issues
- modeling tools, such as Deterministic Network Calculus
- network simulation tools (examples include ns-2/ns-3, OMNET)

SKILLS

- Service models for field bus and their limitation
- utilizing consistency between automates in a distributed system
- describing a loose coupled system with basic traffic pattern modeling
- home automation and similar domain areas in perspective of communication and safety
- quality of service
- protocol design

COMPETENCES

- identify requirements and select an appropriate communication architecture
- analyze and design complex networked systems with hard requirements such as providing real time guarantees
- model system behavior using analytical or simulation tools

TYPE OF INSTRUCTION

As described in § 17.

EXAM

EXAMS

Name of exam	Distributed Real Time Systems
Type of exam	Written or oral exam
ECTS	5
Assessment	Passed/Not Passed
Type of grading	Internal examination

Criteria of assessment	The criteria of assessment are stated in the Examination Policies and Procedures

FACTS ABOUT THE MODULE

Danish title	Distribuerede realtidssystemer
Module code	ESNCAK1K2F
Module type	Course
Duration	1 semester
Semester	Autumn
ECTS	5
Language of instruction	English
Empty-place Scheme	Yes
Location of the lecture	Campus Aalborg
Responsible for the module	Ove Kjeld Andersen

ORGANISATION

Study Board	Study Board of Electronics and IT
Department	Department of Electronic Systems
Faculty	Technical Faculty of IT and Design

ROBUST COMMUNICATIONS AND TRAFFIC ANALYSIS

2020/2021

CONTENT, PROGRESS AND PEDAGOGY OF THE MODULE

LEARNING OBJECTIVES

KNOWLEDGE

The students must have insight in:

- traffic modelling including heavy tailed behavior
- renewal processes, self-similar traffic and long-range dependence
- advanced queuing models, including matrix analytical and matrix exponential models
- different types of faults that can occur during the operational phase of a communication system
- dependability concepts; availability & reliability for parallel and serial systems
- methods for fault-detection and fault-recovery, incl Markov chain models for systems with faults
- Hidden Markov models for fault detection

SKILLS

Students must be able to

- apply simple and advanced traffic and queuing models, in performance analysis of real-life traffic systems
- create realistic traffic models, based on knowledge on the behavior of relevant components including users and applications and/or on knowledge of existing traffic
- list the different considered faults, how they propagate through the system and assess their severity and occurrence likelihood
- quantitatively assess the impact of faults on system availability and system reliability
- apply methods for fault-detection and recovery to complex networked systems, including cyber-physical systems
- Develop fault tolerant strategies for ensuring the continuation of the system in the presence of faults

COMPETENCES

The students must be able to

- select the appropriate queuing and traffic models to be used in the modeling of a specific system, analyse them and apply
- Select fault-tolerant strategies for a given distributed system.
- systematically analyze distributed, networked systems and feedback the analysis results into an efficient, fault-tolerant system design

TYPE OF INSTRUCTION

Types of instruction are listed at the start of §17; Structure and contents of the programme.

EXAM

EXAMS

Name of exam	Robust Communications and Traffic Analysis
Type of exam	Written or oral exam
ECTS	5
Assessment	Passed/Not Passed

Type of grading	Internal examination
Criteria of assessment	The criteria of assessment are stated in the Examination Policies and Procedures

FACTS ABOUT THE MODULE

Danish title	Robust kommunikation og trafikanalyse
Module code	ESNCTK2K2
Module type	Course
Duration	1 semester
Semester	Spring
ECTS	5
Language of instruction	English
Location of the lecture	Campus Aalborg
Responsible for the module	Tatiana Kozlova Madsen

ORGANISATION

Study Board	Study Board of Electronics and IT
Department	Department of Electronic Systems
Faculty	Technical Faculty of IT and Design

NETWORK SECURITY

2020/2021

CONTENT, PROGRESS AND PEDAGOGY OF THE MODULE

LEARNING OBJECTIVES

KNOWLEDGE

The students must have insight in:

- Cybercrime and different kinds of cyberattacks, including the underlying motivations and techniques.
- Different malware types
- Network-based threats and botnets
- Security challenges in various services and applications, for example Internet of Things and Industry 4.0.
- Security protocols and wireless security.
- Traffic monitoring and analysis

SKILLS

The students must have understanding of

- Methods for network-based prevention, detection and analysis of network-based cyber-attacks, including analysis of traffic at different layers of the TCP/IP protocol stack.
- Penetration testing tools
- Configuration and operation of secure environments for cyber security training and research.
- basic techniques for network monitoring and analysis; their use in the cyber security domain; and evaluation of which techniques can be used to solve a given problem.

COMPETENCES

The students must be able to

- Evaluate which methods and tools for detecting, preventing and analyzing network-based attacks should be used for a specific case/problem

TYPE OF INSTRUCTION

Types of instruction are listed in §17; Structure and contents of the programme.

EXAM

EXAMS

Name of exam	Network Security
Type of exam	Written or oral exam
ECTS	5
Assessment	Passed/Not Passed
Type of grading	Internal examination
Criteria of assessment	The criteria of assessment are stated in the Examination Policies and Procedures

FACTS ABOUT THE MODULE

Danish title	Netværkssikkerhed
Module code	ESNCTK2K5
Module type	Course
Duration	1 semester
Semester	Spring
ECTS	5
Language of instruction	English
Empty-place Scheme	Yes
Location of the lecture	Campus Aalborg
Responsible for the module	Tatiana Kozlova Madsen

ORGANISATION

Study Board	Study Board of Electronics and IT
Department	Department of Electronic Systems
Faculty	Technical Faculty of IT and Design

AVANCEREDE EMNER INDEN FOR DISTRIBUEREDE SYSTEMER

2020/2021

MODULETS INDHOLD, FORLØB OG PÆDAGOGIK

LÆRINGSMÅL

VIDEN

opnå viden om videregående teorier og metoder inden for distribuerede og indlejrede systemer:

- avancerede infrastrukturer og applikationer for fx. grid-, cloud-, peer-to-peer-, eller parallelle/multi-core-systemer
- system og netværksprogrammel til indlejrede systemer
- eksempler på distribuerede indlejrede systemer, såsom ad-hoc sensor networks, home automation
- distribuerede algoritmer, såsom algoritmer til gensidig, udelukkelse, udvælgelse, consensus, replikering og fejltolerance
- paradigmer til programmering
- teknikker til analyse, såsom monitorering, test, verifikation, og benchmarking

FÆRDIGHEDER

- kunne redegøre for præcist og ved brug af fagets terminologi og notation for, og vurdere hvordan og i hvilket omfang de præsenterede resultater kan anvendes
- kunne bruge de fornødne skriftlige færdigheder i disse sammenhænge

KOMPETENCER

- kunne anvende begreber og teknikker fra distribuerede systemer, samt designe og analysere distribuerede og indlejrede systemer

UNDERVISNINGSFORM

Undervisningen tilrettelægges i henhold til de generelle undervisningsformer for uddannelsen, jf. kapitel 3

OMFANG OG FORVENTET ARBEJDSINDSATS

Det forventes at den studerende bruger 30 timer per ECTS, hvilket for denne aktivitet betyder 150 timer.

EKSAMEN

PRØVER

Prøvens navn	Avancerede emner inden for distribuerede systemer
Prøveform	Skriftlig eller mundtlig
ECTS	5
Bedømmelsesform	7-trins-skala
Censur	Intern prøve
Vurderingskriterier	Vurderingskriterierne er angivet i Universitetets eksamensordning

YDERLIGERE INFORMATIONER

Kontakt: Studienævn for datalogi via cs-sn@cs.aau.dk eller 9940 8854

FAKTA OM MODULET

Engelsk titel	Advanced Topics in Distributed Systems
Modulkode	DSNDATFK103
Modultype	Kursus
Varighed	1 semester
Semester	Efterår
ECTS	5
Undervisningssprog	Dansk og engelsk
Tomplads	Ja
Undervisningssted	Campus Aalborg
Modulansvarlig	Lone Leth Thomsen

ORGANISATION

Studienævn	Studienævn for Datalogi
Institut	Institut for Datalogi
Fakultet	Det Tekniske Fakultet for IT og Design