Curriculum for the Master’s Programme in Networks and Distributed Systems

Aalborg University
September 2018
Preface:
Pursuant to Act 261 of March 18, 2015 on Universities (the University Act) with subsequent changes, the following curriculum for the Master's programme in Networks and Distributed Systems is stipulated. The programme also follows the Joint Programme Regulations and the Examination Policies and Procedures for The Technical Faculty of IT and Design.
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Chapter 1: Legal Basis of the Curriculum, etc.

1.1 Basis in ministerial orders
The Master’s programme in Networks and Distributed Systems is organised in accordance with the Ministry of Higher Education and Science’s Order no. 1328 of November 15, 2016 on Bachelor’s and Master’s Programmes at Universities (the Ministerial Order of the Study Programmes) and Ministerial Order no. 1062 of June 30, 2016 on University Examinations (the Examination Order). Further reference is made to Ministerial Order no. 111 of January 30, 2017 (the Admission Order) and Ministerial Order no. 114 of February 3, 2015 (the Grading Scale Order) with subsequent changes.

1.2 Faculty affiliation
The Master’s programme falls under The Technical Faculty of IT and Design, Aalborg University.

1.3 Board of Studies affiliation
The Master’s programme falls under the Board of Studies for Electronics and IT.

1.4 External Examiners Corps
The Master’s programme is associated with the external examiners for engineering educations: electro (In Danish: censorkorps for Ingeniøruddannelsernes landsdækkende censorkorps; elektro).

Chapter 2: Admission, Degree Designation, Programme Duration and Competence Profile

2.1 Admission
Applicants with a legal claim to admission (retnskrav):
Aalborg University offers no bachelor’s programmes with a legal right of admission to this Master’s program.

Applicants without legal claim to admission:
Bachelor’s programmes qualifying students for admission:
- Bachelor of Science (BSc) in Engineering (Electronic Engineering and IT with specialisation in Communication Systems) (AAU)
- Bachelor of Science (BSc) in Engineering (Electronic Engineering and IT with specialisation in Signal Processing) (AAU)
- Bachelor of Science (BSc) in Engineering (Electronic Engineering and IT with specialisation in Informatics) (AAU)
- Bachelor of Science in Engineering (Electronic Engineering and IT with specialisation in Control Engineering), Aalborg University
- Bachelor of Science (BSc) in Engineering (Internet Technologies and Computer Engineering with specialisation in Communication Systems) (AAU)
- Bachelor of Science (BSc) in Engineering (Internet Technologies and Computer Engineering with specialisation in Signal Processing) (AAU)
- Bachelor of Science (BSc) in Engineering (Internet Technologies and Computer Engineering with specialisation in Informatics)
- Bachelor of Science (BSc) in Engineering (Internet Technologies and computer Engineering with specialisation in Control Engineering), Aalborg University
- Bachelor of Science in Engineering (Robotics); Aalborg University
- Bachelor of Science (BSc) in Engineering (Mathematical Engineering).
- Bachelor of Science (BSc) in Engineering (Electronics and Computer Engineering) (AAU Esbjerg)
- Bachelor of Engineering (BScEE) in Electronics (AAU)
- Bachelor of Engineering (BScEE) in Electronics (AU)
2.2 Degree designation in Danish and English
The Master’s programme entitles the graduate to the designation civilingeniør, cand.polyt. (candidatus/candidata polytechnices) i netværk og distribuerede systemer. The English designation is: Master of Science (MSc) in Engineering (Networks and Distributed Systems).

2.3 The programme’s specification in ECTS credits
The Master’s programme is a 2-year, research-based, full-time study programme. The programme is set to 120 ECTS credits.

2.4 Competence profile on the diploma
The following competence profile will appear on the diploma:

A graduate of the Master’s programme has competencies acquired through an educational programme that has taken place in a research environment.

The graduate of the Master’s programme can perform highly qualified functions on the labour market on the basis of the educational programme. Moreover, the graduate has prerequisites for research (a Ph.D. programme). Compared to the Bachelor’s degree, the graduate of the Master’s programme has developed her/his academic knowledge and independence, so that the graduate can independently apply scientific theory and method in both an academic and occupational/professional context.

2.5 Competence profile of the programme:

The graduate of the Master’s programme:

Knowledge
- Has an understanding of the concept of complex distributed systems
- Has an understanding of methods within network planning.
- Has an understanding of network design of both general purpose, multipurpose and dedicated networks.
- Has knowledge in one or more subject areas that is based on the highest international research within the fields of networks and distributed systems

Skills
- Can analyze and apply methods, including analytical, numerical and experimental methods, for analysis, design and test of networks and distributed systems, including systems with reliability and/or timing requirements.
- Demonstrate insight in relevant theories, methods and techniques used for distribution, storage and processing of data in a distributed system.
- Demonstrate insight in real-time, performance, safety and robustness aspects.
- Can apply modeling methods for the behavior of a network,
 Competencies

- Have a deep understanding of analysis and design of networks, distributed systems and applications within this domain.
- Can select and apply appropriate methods for solving a given problem within networks and distributed systems and evaluate the results regarding their accuracy and validity.
- Can identify scientific problems within networks and distributed systems and select and apply proper scientific theories, methods and tools for their solution.
- Can develop and advance new analyses and solutions within networks and distributed systems.
- Can manage work-related situations that are complex and unpredictable, and which require new solutions.
- Can initiate and implement discipline-specific as well as interdisciplinary cooperation and assume professional responsibility.
- Can take responsibility for own professional development and specialization.
- 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.

Chapter 3: Content and Organization of the Programme

The programme is structured in modules and organised as a problem-based study. A module is a programme element or a group of programme elements, which aims to give students a set of professional skills within a fixed time frame specified in ECTS credits, and concluding with one or more examinations within specific exam periods. Examinations are defined in the curriculum.

The programme is based on a combination of academic, problem-oriented and interdisciplinary approaches and organised based on the following work and evaluation methods that combine skills and reflection:

- lectures
- classroom instruction
- project work
- workshops
- exercises (individually and in groups)
- teacher feedback
- reflection
- portfolio work

3.1 Overview of the programme:
All modules are assessed through individual grading according to the 7-point scale or Pass/Fail. All modules are assessed by external examination (external grading) or internal examination (internal grading or by assessment by the supervisor only).

<table>
<thead>
<tr>
<th>Semester</th>
<th>Module</th>
<th>P/C*</th>
<th>ECTS</th>
<th>Assessment</th>
<th>Exam</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st</td>
<td>Networks and distributed systems</td>
<td>P</td>
<td>15</td>
<td>7-point scale</td>
<td>Internal</td>
</tr>
<tr>
<td></td>
<td>Stochastic Processes</td>
<td>C</td>
<td>5</td>
<td>7-point scale</td>
<td>Internal</td>
</tr>
<tr>
<td></td>
<td>Distributed Real Time Systems</td>
<td>C</td>
<td>5</td>
<td>Pass/Fail</td>
<td>Internal</td>
</tr>
<tr>
<td></td>
<td>Wireless PHY/MAC Fundamentals (Elective)</td>
<td>C</td>
<td>5</td>
<td>Pass/Fail</td>
<td>Internal</td>
</tr>
<tr>
<td></td>
<td>Communication Networks and Ambient Intelligence (Elective)</td>
<td>C</td>
<td>5</td>
<td>Pass/Fail</td>
<td>Internal</td>
</tr>
<tr>
<td>2nd</td>
<td>Distributed Systems Design</td>
<td>P</td>
<td>15</td>
<td>7-point scale</td>
<td>External</td>
</tr>
<tr>
<td></td>
<td>Wireless Systems Performance</td>
<td>C</td>
<td>5</td>
<td>Pass/Fail</td>
<td>Internal</td>
</tr>
<tr>
<td></td>
<td>Fault Detection, Isolation and Modelling</td>
<td>C</td>
<td>5</td>
<td>Pass/Fail</td>
<td>Internal</td>
</tr>
<tr>
<td></td>
<td>Network Performance and Applications</td>
<td>C</td>
<td>5</td>
<td>Pass/Fail</td>
<td>Internal</td>
</tr>
<tr>
<td>3rd</td>
<td>A</td>
<td>Performance Analysis and Network Planning</td>
<td>P</td>
<td>20</td>
<td>7-point scale</td>
</tr>
<tr>
<td></td>
<td>Systems of Systems/Complex Systems (Elective)</td>
<td>C</td>
<td>5</td>
<td>Pass/Fail</td>
<td>Internal</td>
</tr>
<tr>
<td></td>
<td>Machine Learning (Elective)</td>
<td>C</td>
<td>5</td>
<td>Pass/Fail</td>
<td>Internal</td>
</tr>
<tr>
<td></td>
<td>Non-linear Control (Elective)</td>
<td>C</td>
<td>5</td>
<td>Pass/Fail</td>
<td>Internal</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Academic Internship</td>
<td>P</td>
<td>20¹, 25², 30</td>
<td>7-point scale</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>Long Master’s Thesis</td>
<td>P</td>
<td>15, 20 or 30³</td>
<td>7-point scale</td>
</tr>
<tr>
<td>4th</td>
<td>Master’s Thesis</td>
<td>P</td>
<td>30</td>
<td>7-point scale</td>
<td>External</td>
</tr>
<tr>
<td>Total</td>
<td>120</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* P = project  
  C = course

¹ If choosing a 20 ECTS academic internship the student must earn the remaining credits on the 3rd semester by following two of the elective courses under option A  
² If choosing a 25 ECTS academic internship the student must earn the remaining credits on the 3rd semester by following one of the elective courses under option A  
³ If choosing to write long master’s thesis of less than 60 ECTS the student must earn the remaining credits on the 3rd semester by following elective courses under option A
3.2 Descriptions of modules
3.2.1 - 1st Semester

**Networks and Distributed Systems (15 ECTS)**
*Netværk og distribueret processering (Fokus på videnskabelig kommunikation)*

Objective:
Students who complete the module:

Knowledge
Must have knowledge about:
- distribution, storage and processing of data in a distributed system
- at least one of the following aspects: real-time, performance, safety, robustness, mobility and positioning aspects

Skills
Must be able to:
- conduct synthesis of theories, methods and techniques used for distribution, storage and processing of data in a distributed system
- apply relevant theories, methods and techniques to the chosen system to ensure that at least one of the following requirements are satisfied:
  - timing requirements in connection with distribution, storage and processing of data are satisfied
  - performance, safety and robustness requirements are satisfied
  - mobility and positioning requirements are satisfied
- can explain the process of and criteria for peer reviewed and scientific communications
- can write a paper for a scientific conference/journal
- can prepare and give an oral and poster presentation for a scientific conference

Competencies
Must have the ability to:
- read and understand selected scientific literature and next apply the theories, methods, and/or tools in order to solve a problem which requires distribution of networking or processing functionalities.
- 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

Type of instruction:
As described in the introduction to Chapter 3.

Exam format:
Individual oral examination. The examination is based on questions that take their starting points in the written documentation for the project module. For further information concerning the examination procedure, refer to the Joint Programme Regulations.

Evaluation criteria:
As stated in the Joint Programme Regulations
Stochastic Processes (5 ECTS)

Stokastiske processer

Recommend academic prerequisites:
The module builds on knowledge of probability, statistics, linear algebra, Fourier theory, and programming

Objective:
Students who complete the module must:

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.

Competencies
• 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 the introduction to Chapter 3.

Exam format:
Individual oral or written examination.

For further information concerning the examination procedure, refer to the Joint Programme Regulations.

Evaluation criteria:
As stated in the Joint Programme Regulations.
Distributed Real Time Systems (5 ECTS)

Distribuerede realtidssystemer

Recommended academic prerequisites:
The module builds on knowledge of basic network communication and protocols as e.g. obtained in the courses Communication in Electronic Systems (EIT 5th Semester) or Network technologies and distributed systems (ITC 5th Semester)

Objective:
Students who complete the module:

Knowledge
The students must have insight in:
- 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
The students must have understanding of …
- 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

Competencies
The students must be able to
- 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 the introduction to Chapter 3.

Exam format:
Individual oral or written examination. For further information concerning the examination procedure, refer to the Joint Programme Regulations.

Evaluation criteria:
As stated in the Joint Programme Regulations
Wireless PHY/MAC Fundamentals (5 ECTS)
Trådløse PHY and MAC grundbegreber

Recommended academic prerequisites:
The module builds on a basic understanding of wireless communications fundamentals, mathematics and statistics corresponding to knowledge obtained during a BSc in Electrical Engineering

Objective:
Students who complete the module:

Knowledge
Must have knowledge about the following:

- Fundamental communication theory for wireless transmission
  - Classical communication theory
  - Noise handling in wireless communications
    - Loss and channel models (Friis transmission formula)
    - Analog chains, noise factor
    - Digital chains, coding
  - Detection and demodulation theory (coherent vs non-coherent)
- Transceiver architectures, blocks and components
  - Transceiver structures and synchronization (incl. duplexing and access aspects)
  - Non-ideal components (non-linearities, compression and intercept)
  - Dynamic range and link budget
  - S-parameter description of components
  - RF/u-wave measurements of wireless communication blocks and chains
- Modeling and simulation of transceiver systems
  - Complex baseband representation of pass-band communication
  - Signal distortion due to block imperfections

Skills
Must be able to:

- Establish a link budget
- Synthesize a transceiver system on a block diagram level
- Describe the modifications that a signal undergoes through a transceiver chain
- Calculate key performance characteristics for a full transceiver chain based on specifications for the individual blocks
- Simulate the transmission of digital data through a full transceiver chain – including transmitter, lossy and noisy wireless channel, and receiver

Competencies
- Must be able to:
  - 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:
As described in the introduction to Chapter 3.

Exam format:
Individual oral or written examination.

Evaluation criteria:
As stated in the Joint Programme Regulations
Objective:
Students who complete the module:

Knowledge
Knowledge

- Must have knowledge about general network models and architectures including the OSI model (MAC, transport, network and application layers) as well as the TCP/IP protocol stack (IP, TCP and UDP protocols).

- Must have knowledge about selected technologies within Internet of Things (IoT), including wireless sensors, wireless sensor networks and RFID, and their application within IoT.

- Must have knowledge of simulation tools.

- Must have knowledge of protocols for unicast, multicast and broadcast.

Skills

- Must be able to understand the OSI model and the TCP/IP protocol stack at such a level that they are able to model selected data link, network, transport, and application layer protocols.

- Must be able to monitor and observe traffic from different networks, and to use the observations for creating simple traffic models that can be used for simulations.

- Must be able to describe and evaluate basic security mechanisms.

- Must be able to select and compare methods for traffic engineering at data link, network and transport layers: in particular the students must be able to understand how Quality of Service mechanisms are actually implemented through e.g. marking and queuing policies.

- Must be able to understand the RFID and Sensor networking and protocols at such a level that they are able to model selected parts of such protocols.

- Must be able to apply relevant methods for designing services and applications based on RFID and wireless sensor networks.

Competencies

- Must be able to compare different network technologies and configurations by selecting and using appropriate methods, including analysis, simulation and experiments.

- Must have understanding of the scenarios where IoT can be applied, both from technical and business viewpoints, identifying possible new services and applications.

- Must have understanding of a network's topology and its topological properties and qualities.

Type of instruction:
As described in the introduction to Chapter 3.

Exam format:
Individual oral or written examination. For further information concerning the examination procedure, refer to the Joint Programme Regulations.

Evaluation criteria:
As stated in the Joint Programme Regulations
3.2.2 - 2nd Semester

**Distributed Systems Design (15 ECTS)**

*Design af distribuerede systemer*

Recommended academic prerequisites:
Builds on knowledge obtained during the 1st semester

Objective:
Students who complete the module:

**Knowledge**
Must have knowledge about:
- system design methodologies within distributed systems in general
- major performance measures in distributed systems
- design choices w.r.t. how architecture, topology and technology influence various performance measures, including among others location-based services

**Skills**
Must be able to:
- demonstrate understanding at analysis level of system design methodologies within distributed systems in general, and understanding at synthesis level of selected design methodologies.
- demonstrate understanding at analysis level of major performance measures in distributed systems of various scales.
- explain design choices wrt architecture, topology and technology, and be able to analyze how this influence various performance measures.

**Competencies**
Must have the ability to:
- undertake the construction of well-functioning distributed systems and associated communication facilities

**Type of instruction:**
As described in the introduction to Chapter 3.

**Exam format:**
Individual oral examination. The examination is based on questions that take their starting points in the written documentation for the project module. For further information concerning the examination procedure, refer to the Joint Programme Regulations

**Evaluation criteria:**
As stated in the Joint Programme Regulations
Wireless Systems Performance (5 ECTS)
Trådløs system performance

Recommended academic prerequisites:
The module builds on skills and competences within electronic engineering and telecommunications engineering

Objective:
Students who complete the module:

Knowledge
Must have knowledge about the following:
- Link budget analysis
- Wave types
- Power vs protection margins
- Dynamic radio channel characterization
- Short terms descriptions
- Channel hardening/Diversity
- Radio Resource allocation
- Methods for fixed and dynamic channel allocation
- Cellular concept and hand-over
- Link and MAC control, Power control, AMC
- Wireless network performance and traffic analysis
- Dynamic routing
- Transport – congestion control – performance impact
- Wireless network architectures
- Short range infra-structures
- Cellular infra-structure

Skills
The students must be able to
- Establish a link budget with account for dynamic protection margins for a given wireless communication system
- Select the relevant metrics to establish and estimate Quality of Service (QoS) performance
- Establish radio resource requirements based on traffic load
- Evaluate feasibility of routing strategies based on system properties and requirements
- Evaluate and select different wireless networking architectures based on system requirements
- Evaluate properties of dynamic channels and apply stabilization techniques

Competencies
The students must be able to
- Analyze, evaluate and model the chain from PHY to Transport layer and how it combines towards the total performance and QoS of a wireless communication system

Type of instruction:
As described in the introduction to Chapter 3.

Exam format:
Individual oral or written examination. For further information concerning the examination procedure, refer to the Joint Programme Regulations.

Evaluation criteria:
As stated in the Joint Programme Regulations.
Fault detection, Isolation and Modelling (5 ECTS)
Fejldetektion, -isolation og -modellering

Recommended academic prerequisites:
The module builds on knowledge of basic probability theory, dynamical systems formulated in state space and frequency, and the module Stochastic Processes

Objective:
Every real life system will at some point or another experience faults. Students who complete this course will be able to, in a systematic manner, to analyze dynamic systems as well as distributed, network coupled systems. For each of the two system types the student will be able to:

- List the different considered faults, how they propagate through the system and assess their severity and occurrence likelihood.
- Develop methods for estimating if a given fault is present or not.
- Develop fault tolerant strategies for ensuring the continuation of the system in the presence of faults.

Students who complete the module will have:

Knowledge
- Of the taxonomy of fault tolerant systems
- Of simulation tools for testing and verification

Skills
- In analyzing a system for possible faults and modeling these
  - Failure Mode and Effect Analysis
  - Structural analysis
  - Faults in TCP/IP based Networks
- In evaluating the severity of different faults and prioritizing
  - By means of simulations
  - Stochastic models for components and their availability
- In designing detectors for selected faults
  - Structural analysis
    - Analytical Redundancy Relations
  - Passive fault detection
    - Unknown input observers
    - Parameter estimators
    - Parity space filters
  - Active fault detection
    - Design of perturbation signals
    - Neighbor discovery
    - Round-trip time
    - Heartbeats
    - Acknowledged transmissions
  - Decision ruling
- Threshold based
- Stochastic based

- In designing strategies for handling faults
  - Passive fault tolerance
    - Robust controllers
    - Reliable message broadcasting
    - Multipath routing
  - Active fault tolerance
    - Control strategy change
    - Redundant systems with backup components

**Competencies**
- In designing fault tolerance strategies for a given system

**Type of instruction:**
As described in the introduction to Chapter 3.

**Exam format:**
Individual oral or written examination.

For further information concerning the examination procedure, refer to the Joint Programme Regulations.

**Evaluation criteria:**
As stated in the Joint Programme Regulations.
Network Performance and Applications (5 ECTS)
Netværksperformance og applikationer

Recommended academic prerequisites:
The module builds on knowledge obtained in the modules Stochastic Processes and Distributed Real Time Systems

Objective:
Students who complete the module:

**Knowledge**
- Must have knowledge about the network planning process, including the planning of backbone, distribution and access networks, and of the tools involved in this process.
- Must have knowledge of network topologies and structural quality of service.
- Must have knowledge of GIS data and handling of these.
- Must have knowledge about localization techniques.
- Must have knowledge about advanced queuing models, including matrix analytical and matrix exponential models

**Skills**
- Must be able to understand simple and advanced traffic and queuing models, and apply these in analysis of real-life traffic systems.
- Must be able to apply the knowledge of advanced traffic and queuing models in performance analysis based on simulation as well as analysis.
- Must be able to create realistic traffic models, based on knowledge on the behavior of relevant components including users and applications and/or on knowledge of existing traffic.
- Must be able to apply knowledge of network planning tools and methods in a concrete project of limited scale.

**Competencies**
- Must be able to select the appropriate queuing and traffic models to be used in the modeling of a specific system.

Type of instruction:
As described in the introduction to Chapter 3.

Exam format:
Individual oral or written examination. For further information concerning the examination procedure, refer to the Joint Programme Regulations.

Evaluation criteria:
As stated in the Joint Programme Regulations.
3.2.3 – 3rd Semester

Performance Analysis and Network Planning (20 ECTS)
Performanceanalyse og netværksplanlægning

Recommended academic prerequisites:
The project module builds on knowledge obtained during the 1st and 2nd semester

Objective:
Students who complete the module:

Knowledge
Must have knowledge about at least one of the following:

- tools and methods for planning large scale communication systems.
- tools and methods for distributed systems management and security.
- tools and methods for positioning in distributed systems

Skills
Must be able to:

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

Competencies
Must have the ability to:

- make a choice of parameters, methods and tools for the analysis of a problem where a distributed system and/or communication system comprises a part of the solution. Emphasis is on the communication facility and the associated network planning.

Type of instruction:
As described in the introduction to Chapter 3.

Exam format:
Individual oral examination. The examination is based on questions that take their starting points in the written documentation for the project module. For further information concerning the examination procedure, refer to the Joint Programme Regulations.

Evaluation criteria:
As stated in the Joint Programme Regulations.
Recommended academic prerequisites:
The module builds on knowledge within the areas of systems and control theory, network theory, distributed systems and embedded systems

Objective:
The students will be introduced to methodologies for design of a system of systems in terms of designing the properties of the individual systems as well as their interconnecting behavior, establishing the system of systems. A systematic approach to the design of network architectures and local behavior rules, which together constitute systems of systems that are optimal with respect to objectives formulated at a macroscopic level, will be presented.

Students who complete the module:

Knowledge
- The formalized concept of systems of systems
- A systematic approach to the design of network architectures and local behavior rules, which together constitute systems of systems that are optimal with respect to objectives formulated at a macroscopic level.

Skills
- To combine the areas of systems and control theory, network theory, distributed systems and embedded systems into design principles for systems of systems

Competencies
- Design of the properties of the individual systems, as well as their interconnecting behavior, establishing the system of systems
- Identify systems as being complex and/or to fit the Systems of systems paradigm
- Identify appropriate tools for the analysis of complex systems/Systems of systems
- Predict how overall design decisions impact behavior and performance of complex systems/system of systems

Type of instruction:
As described in the introduction to Chapter 3.

Exam format:
Individual oral or written examination.

For further information concerning the examination procedure, refer to the Joint Programme Regulations.

Evaluation criteria:
As stated in the Joint Programme Regulations.
Machine Learning (elective) (5 ECTS)

Machine learning

Recommended academic prerequisites:
The module builds on basic knowledge of Probability Theory, Statistics, and Linear Algebra

Objective:
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.

Students who complete the module:

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.

Competencies
- 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 the introduction to Chapter 3.

Exam format:
Individual oral or written examination.
For further information concerning the examination procedure, refer to the Joint Programme Regulations.

Evaluation criteria:
As stated in the Joint Programme Regulations.
Objective:
Students who complete the module will obtain skills within Nonlinear Control including analysis of controllability, observability, and stabilizability and stability, along with control synthesis for non-linear systems, hybrid systems covering dynamical system with both discrete and continuous components, the optimal linear estimator - the Kalman filter - as well as non-linear estimation and sensor fusion.

Students who complete the module will have:

Knowledge
- Lyapunov stability
- Backstepping
- Linear Kalman Filters and their limitations
- The extended Kalman filter
- The unscented Kalman filter
- Particle filtering
- Kalman filters as parameter estimators
- The influence of (coloured) sensor and model noise on the filter estimate.
- Must be able to understand…
- The invariance principle
- Feedback linearization

Skills
- Controllability
- Observability
- Online estimation techniques to a given system
- Understand and analyze systems with multiple sensors for the purpose of fusing sensor information to control-relevant information
- Stabilizability

Competencies
- Synthesis of non-linear control systems
- Synthesis of hybrid control systems
- Synthesis of estimators for non-linear systems

Type of instruction:
As described in the introduction to Chapter 3.

Exam format:
Individual oral or written examination. For further information concerning the examination procedure, refer to the Joint Programme Regulations.

Evaluation criteria:
As stated in the Joint Programme Regulations.
Academic internship

Projektorienteret forløb i en virksomhed

Recommended academic prerequisites:
An academic internship agreement approved by the company, an AAU supervisor and the study board for electronics and it (ESN).

The academic internship must have a scope that correspond the ECTS load.

Purpose:
The student stays in a company with the purpose of learning and applying theories and methods to address engineering problems in an industrial context. In addition, the student will be introduced to business procedures and policies.

Objectives:
After completing the module, the student should have the following knowledge, skills and competencies:

Knowledge
- Has knowledge about the organization of the company and business procedures and policies.
- Has knowledge about performance measures in the company.
- Has developed a fundamental business sense.
- Has knowledge of the competence profile of the program and how the academic internship contributes to the competence profile.
- Has gained deepened knowledge into engineering theories and methods within the program.

Skills
- Can initiate and ensure the completion of an agreement for the academic internship, with learning objectives corresponding to the semester at the master’s program.
- Can apply analytic, methodological and/or theoretic skills to address advanced engineering problems in an industrial context.
- Can contribute in a professional manner to company objectives as an individual and in teams in accordance with the project management model applied in the company.
- Can collaborate and communicate with peers, managers and others.
- Can document the academic internship in a report and defend it orally.

Competencies
- Can discuss and reflect on the learning outcomes of the academic internship.
- Can discuss the need for knowledge transfer between academia and industry.
- Has a deepened understanding of the academic interests to pursue in the master’s thesis and possible job positions to aim at after graduation.

Type of instruction:
Project work

Exam format:
Oral examination based on a written report.

Evaluation criteria:
As stated in the Joint Programme Regulations.
Master's Thesis (30, possibly 45, 50 or 60 ECTS)

Kandidatspeciale

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.

Recommended academic prerequisites:
The master’s thesis build on knowledge obtained during the 1st – 4th Semester

Objective:
Students who complete the module:

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.

Competencies
- 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:
As described in the introduction to Chapter 3.

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

Exam format:
Individual oral examination. An external censor is appointed.
The examination is based on questions that take their starting points in the written documentation for the project module.

For further information concerning the examination procedure, refer to the Joint Programme Regulations.

Evaluation criteria:
As stated in the Joint Programme Regulations.
Chapter 4: Entry into Force, Interim Provisions and Revision

The curriculum is approved by the Dean of The Technical Faculty of IT and Design and enters into force as of September 2018.

Students who wish to complete their studies under the previous curriculum from 2017 must conclude their education by the summer examination period 2019 at the latest, since examinations under the previous curriculum are not offered after this time.

Chapter 5: Other Provisions

5.1 Rules concerning written work, including the Master's thesis
In the assessment of all written work, regardless of the language it is written in, weight is also given to the student's spelling and formulation ability, in addition to the academic content. Orthographic and grammatical correctness as well as stylistic proficiency are taken as a basis for the evaluation of language performance. Language performance must always be included as an independent dimension of the total evaluation. However, no examination can be assessed as ‘Pass’ on the basis of good language performance alone; similarly, an examination normally cannot be assessed as ‘Fail’ on the basis of poor language performance alone. The Board of Studies can grant exemption from this in special cases (e.g., dyslexia or a native language other than Danish).

The Master’s thesis must include an English summary.\(^4\) If the project is written in English, the summary must be in Danish.\(^5\) The summary must be at least 1 page and not more than 2 pages. The summary is included in the evaluation of the project as a whole.

5.2 Rules concerning credit transfer (merit), including the possibility for choice of modules that are part of another programme at a university in Denmark or abroad
The Board of Studies can approve successfully completed (passed) programme elements from other Master's programmes in lieu of programme elements in this programme (credit transfer). The Board of Studies can also approve successfully completed (passed) programme elements from another Danish programme or a programme outside of Denmark at the same level in lieu of programme elements within this curriculum. Decisions on credit transfer are made by the Board of Studies based on an academic assessment. See the Joint Programme Regulations for the rules on credit transfer.

5.3 Rules for examinations
The rules for examinations are stated in the Examination Policies and Procedures published by the Technical Faculty of IT and Design on their website.

All students who have not participated in Aalborg University’s PBL introductory course during their Bachelor’s degree must attend the introductory course “Problem-based Learning and Project Management”\(^6\). The introductory course must be approved before the student can participate in the project exam. For further information, please see the School of Information and Communication Technology’s website.

\(^4\) Or another foreign language (upon approval from the Board of Studies)
\(^5\) The Board of Studies can grant exemption from this.
5.4 Exemption
In exceptional circumstances, the Board of Studies study can grant exemption from those parts of the curriculum that are not stipulated by law or ministerial order. Exemption regarding an examination applies to the immediate examination.

5.5 Rules and requirements for the reading of texts
It is assumed that the student can read academic texts in his or her native language as well as in English and use reference works etc. in other European languages.

5.6 Additional information
The current version of the curriculum is published on the Board of Studies' website, including more detailed information about the programme, including exams.