Module catalog for the degree program entitled Information and Communications Engineering

Contact person: Dean FB VII (fb7@beuth-hochschule.de)
Contact person: Prof. Dr. Marcus Purat (marcus.purat@beuth-hochschule.de)

Module number	Module name	Coordinator
M01	Advanced Signal Processing Methods	Prof. Dr. André Jakob
M02	Advanced Signal Transmission Technologies	Prof. Dr. Michael Rohde
M03	Stochastic Modeling and Optimization	Prof. Dr. Marcus Purat
M04	Master Colloquium A	Prof. Dr. Marcus Purat
M05	Required-Elective Module I	Prof. Dr. Marcus Purat
M06	Required-Elective Module II	Prof. Dr. Marcus Purat
M07	Network Engineering	Prof. Dr. David Dietrich
M08	Software Engineering	Prof. Dr. Heike Ripphausen-Lipa / Prof. Dr. Peter Gober
M09	Master Colloquium B	Prof. Dr. Marcus Purat
M10	General Studies I	Prof. Dr. Marcus Purat / Dean FB I
M11	General Studies II	Prof. Dr. Marcus Purat / Dean FB I
M12	Required-Elective Module III	Prof. Dr. Marcus Purat
M13	Required-Elective Module IV	Prof. Dr. Marcus Purat
M14	Final Examination Module	Prof. Dr. Marcus Purat
WP01	Digital Radio Systems	Prof. Dr. Matthias Seimetz
WP02	Model-Based Digital Communication Systems Design	Prof. Dr. Marcus Purat
WP03	Network Security and Cryptography	Prof. Dr. David Dietrich
WP04	Advanced Switching and Routing	Prof. Dr. David Dietrich
WP05	Photonic Communication Systems	Prof. Dr. Michael Rohde
WP06	Multimedia Broadcast Systems	Prof. Dr. Marcus Purat
WP07	Machine Learning	Prof. Dr. Peter Gober
WP08	Distributed Systems and Services	Prof. Dr. David Dietrich

Data field	Explanation
Module number	M01
German title / English title	Fortgeschrittene Methoden der Signalverarbeitung / Advanced Signal Processing Methods
Credits	5 ECTS
Workload	51 Contact hours (2 SWS SU + 1 SWS Ü), 99 Hours of independent study
Subject coverage	Subject-Specific specialization
Learning outcomes	Students know advanced digital signal processing methods and how to apply these methods on one- and two-dimensional signal processing problems.
Requirements	Recommendation: Knowledge of basic digital signal processing concepts
Level	1. Semester
Type of module	Seminar, Laboratory Training
Status	Required module
Semesters when offered	Winter semester
Method of assessment / Type of examination	The method of assessment / type of examination must be defined by the lecturer within the deadline determined in §19 (2) RSPO. Should the deadline pass without determination of the form of assessment in the module, the following method of assessment / type of examination applies: SU written examination (90 minutes), Ü two lab reports (10-15 pages each)
Grade assessment	See study and examination regulations
Content	• Short review of signal processing concepts • Adaptive filters (Wiener filter theory, LMS algorithm, convergence analysis, applications) • Multi-rate signal processing (decimation, interpolation, rational sample rate conversion, multi-stage conversion, polyphase filter structures, CIC filters, M-band filters, two-channel quadrature mirror filter banks, M-channel filter banks, applications) • One- and two-dimensional transforms (DCT, modified DCT, STFT, wavelet transform, applications) • Laboratory training with MATLAB/Simulink on selected topics (e.g. speech synthesis with linear prediction, echo control, microphone beamforming, channel estimation, multi-stage decimation and interpolation)
Reading list	J. G. Proakis/D. G. Manolakis, Digital Signal Processing, Pearson S. Haykin, Adaptive Filter Theory, Pearson R. Lyons, Understanding Digital Signal Processing, Pearson L. Fliege, Multirate Digital Signal Processing, J. Wiley & Sons
Further information	Language employed in the module: English
Required Room type	SU-Sem, Ü-Lab

Data field	Explanation
Module number	M02
German title / English title	Fortgeschrittene Technologien der Signalübertragung / Advanced Signal Transmission Technologies
Credits	5 ECTS
Workload	51 contact hours (2 SWS SU + 1 SWS Ü), 99 hours of independent study
Subject coverage	Subject-specific specialization
Learning outcomes	Students have a deepened understanding of selected advanced signal transmission techniques used in present digital radio systems and fiber-optic transmission systems. Moreover, they can apply this knowledge in typical experimental signal transmission setups.
Requirements	Recommendation: Knowledge of basic signal transmission technologies
Level	1. Semester
Type of module	Seminar, Laboratory Training
Status	Required module
Semesters when offered	Winter semester
Method of assessment / Type of examination	The method of assessment / type of examination must be defined by the lecturer within the deadline determined in §19 (2) RSPO. Should the deadline pass without determination of the form of assessment in the module, the following method of assessment / type of examination applies: SU written examination (90 minutes), Ü Written laboratory report (10-15 pages) of the laboratory group with consultation (15-30 minutes)
Grade assessment	see study and examination regulations
Content	• Short review of aspects of digital communications engineering • Advanced modulation formats (Offset PSK, Differential PSK, π/4-DQPSK, continuous phase modulation, MSK, GMSK) • Coherent detection (homodyne, heterodyne and superheterodyne receiver) • BER performance of different modulation formats • Advanced receiver functions (clock recovery, equalization, carrier synchronization via PLL and frequency / phase estimation, channel estimation) • Advanced detection techniques (matched filter detection, maximum likelihood decoding) • Channel coding (mathematical treatment of block coding and convolutional coding) • Lab exercise (example): computer simulations and lab experiments with transmission systems using advanced modulation formats • Simulative and experimental evaluation of advanced receiver functions
Reading list	Proakis: Digital Communications, McGraw-Hill Kammeyer: Nachrichtenübertragung, Vieweg Werner: Nachrichtentechnik, Vieweg
Further information	Language employed in the module: English
Required Room type	SU-Sem, Ü-Lab

Data field	Explanation
Module number	M03
German title / English title	Stochastische Modellierung und Optimierung / Stochastic Modeling and Optimization
Credits	5 ECTS
Workload	68 Contact hours (4 SWS SU), 82 Hours of independent study
Subject coverage	Subject-Specific specialization
Learning outcomes	Students master the fundamentals of the theory of probability and stochastic processes. They know how stochastic models are applied to practical communications engineering problems in signal processing, signal transmission, network engineering, or parameter estimation and detection, and they can design and analyze optimum systems on the basis of such models.
Requirements	None
Level	1. Semester
Type of module	Seminar
Status	Required module
Semesters when offered	Winter semester
Method of assessment / Type of examination	The method of assessment / type of examination must be defined by the lecturer within the deadline determined in §19 (2) RSPO. Should the deadline pass without determination of the form of assessment in the module, the following method of assessment / type of examination applies: Written examination (120 minutes)
Grade assessment	See study and examination regulations
Content	• Probability, random variables, univariate and multivariate distribution and density function, expected value, moments, correlation • Stochastic processes: ensemble and time average, characteristics of stochastic processes, correlation, power density spectrum • Examples of stochastic processes: Gaussian process and variants, Poisson and Erlang process, Markov chains, ARMA process • Transformation of stochastic processes: non-linear static systems, linear systems with memory • Design and analysis of optimum systems: estimation and detection problem, estimation characteristics, optimization criteria • Applications in communications engineering: e.g. statistic linearization, histogram equalization, Bayes estimation and detection, Maximum-likelihood estimation, linear prediction, Wiener filter, Kalman filter, queuing theory, communication source and channel models, entropy, channel capacity, coding
Reading list	A. Papoulis, S. Pillai: Probability, Random Variables, and Stochastic Processes, McGraw Hill S. Kay: Fundamentals of Statistical Signal Processing, Prentice Hall
Further information	Language employed in the module: English
Required Room type	SU-Sem

Data field	Explanation
Module number	M04
German title / English title	Master-Kolloquium A / Master Colloquium A
Credits	5 ECTS
Workload	17 Contact hours (1 SWS Ü), 133 Hours of independent study
Subject coverage	Advanced interdisciplinary studies
Learning outcomes	Students have advanced knowledge in selected fields of information and communications technology, have an increased competence in the independent acquisition and classification of technical and scientific knowledge in professional practice and in the independent solving of current, practice-related and interdisciplinary problems, and have a solid competence in writing and presenting technical and scientific work results in English or German as a foreign language.
Requirements	none
Level	1. Semester
Type of module	Seminar, Project Work
Status	Required module
Semesters when offered	Winter semester
Method of assessment / Type of examination	The method of assessment / type of examination must be defined by the lecturer within the deadline determined in §19 (2) RSPO. Should the deadline pass without determination of the form of assessment in the module, the following method of assessment / type of examination applies: Project with report (10-15 pages) / Project Presentation (15 minutes)
Grade assessment	See study and examination regulations

Content	• Project work on a selected subject area under the supervision of a university lecturer
	  ○ Development of a case study, a theoretical approach or a practical solution focusing on a systematic approach to solving a problem using state-of-the-art scientific knowledge, and replicability of the results
	  ○ Discussion of current problems in information and communications engineering, preferably in an interdisciplinary context
	• Lectures and presentations of invited speakers on current selected topics in information and communications engineering
	• Written documentation and presentation of the work result

Reading list	Will be specified by the lecturers at the beginning of the course depending on project.
Further information	Language employed in the module: English or German
Required Room type	Ü-Sem

Data field	Explanation
Module number	M05
German title / English title	Wahlpflichtmodul I / Required-Elective Module I
Credits	5 LP
Workload	68 Contact hours (4 SWS Ü), 82 Hours of independent study
Subject coverage	Subject-specific specialization
Learning outcomes	See description of required-elective modules
Requirements	See description of required-elective modules
Level	1. Semester
Type of module	See description of required-elective modules
Status	See description of required-elective modules
Semesters when offered	Winter semester
Method of assessment / Type of examination	See description of required-elective modules
Grade assessment	See description of required-elective modules
Content	Selected subjects depending on selected module from the catalog of required-elective modules For this required-elective module, modules WP01 to WP08 can be selected from the catalog of required-elective modules.
Reading list	See description of required-elective modules
Further information	• The Faculty Council of Faculty VII may decide to provide additional modules as required-elective modules. This decision will be taken before the beginning of the Semester. • Upon application, students may also select a module from another master program at the Beuth-Hochschule für Technik Berlin as required-elective module in the first curriculum semester, provided that the content does not correspond to the required modules of their own study program. The Dean of the Faculty VII decides on the application. • In case of a temporary study abroad, the modules completed there can be fully accredited as required-elective modules, provided that the content does not correspond to the required modules of their own study program. Accrediting will be decided by the Dean of the Faculty VII.
Required Room type	See description of required-elective modules

Data field	Explanation
Module number	M06
German title / English title	Wahlpflichtmodul II / Required-Elective Module II
Credits	5 LP
Workload	68 Contact hours (4 SWS Ü), 82 Hours of independent study
Subject coverage	Subject-specific specialization
Learning outcomes	See description of required-elective modules
Requirements	See description of required-elective modules
Level	1. Semester
Type of module	See description of required-elective modules
Status	See description of required-elective modules
Semesters when offered	Winter semester
Method of assessment / Type of examination	See description of required-elective modules
Grade assessment	See description of required-elective modules
Content	Selected subjects depending on selected module from the catalog of required-elective modules For this required-elective module, modules WP01 to WP08 can be selected from the catalog of required-elective modules.
Reading list	See description of required-elective modules
Further information	• The Faculty Council of Faculty VII may decide to provide additional modules as required-elective modules. This decision will be taken before the beginning of the Semester. • Upon application, students may also select a module from another master program at the Beuth-Hochschule für Technik Berlin as required-elective module in the first curriculum semester, provided that the content does not correspond to the required modules of their own study program. The Dean of the Faculty VII decides on the application. • In case of a temporary study abroad, the modules completed there can be fully accredited as required-elective modules, provided that the content does not correspond to the required modules of their own study program. Accrediting will be decided by the Dean of the Faculty VII.
Required Room type	See description of required-elective modules

Data field	Explanation
Module number	M07
German title / English title	Netzwerktechnik / Network Engineering
Credits	5 ECTS
Workload	51 Contact hours (3 SWS SU), 99 Hours of independent study
Subject coverage	Subject-specific specialization
Learning outcomes	Students know and understand design criteria applicable to local and wide-area networks. They have a working knowledge of defining properties and principles of packet-based carrier-networks. They can analyse and create addressing and naming schemes for IP-based networks and understand current trends in networking research and standardisation. They know protocols and tools for operation, management and troubleshooting of networks.
Requirements	none
Level	2. Semester
Type of module	Seminar
Status	Required module
Semesters when offered	Summer semester
Method of assessment / Type of examination	The method of assessment / type of examination must be defined by the lecturer within the deadline determined in §19 (2) RSPO. Should the deadline pass without determination of the form of assessment in the module, the following method of assessment / type of examination applies: SU: Written examination (90 minutes)
Grade assessment	See study and examination regulations
Content	• Structured Network Design and Analysis of requirements • Definition and analysis of technical goals, such as performance, security, usability and availability • Definition of addressing concepts in IPv4/IPv6 (VLSM, CIDR) • Strategies and properties of naming in the Domain Name System (DNS) • Understand choices and properties for physical connectivity • Structured cabling for campus and datacentre networks: pros and cons of selected transport media • Properties of characteristic network topologies • Ethernet: History, Transparent Bridging, Switching Loops und Spanning Tree Protocol, Virtual LAN concepts (VLANs, Provider-based LANs) • Designing of modular campus networks through the separation of Core, Distribution and Access Layer • Understand approaches and protocols for network management • Test and validation of function, performance and other quality criteria • Understanding design-principles for communication protocols • Principles of Software-Defined Networking • Hands-on exercises to subnetting in IPv4/6 and availability concepts • Classroom discussion and presentations of scientific papers/methods relevant to the field
Reading list	J. Day: Patterns in Network Architecture, Prentice Hall Andrew S. Tanenbaum: Computer Networks. Pearson Studium J. Kurose und K. Ross: Computer Networking. Pearson Studium
Further information	Language employed in the module: English
Required Room type	SU-Sem

Data field	Explanation
Module number	M08
German title / English title	Softwaretechnik / Software Engineering
Credits	5 ECTS
Workload	68 Contact hours (3 SWS SU + 1 SWS Ü),82 Hours of independent study
Subject coverage	Subject-specific principles
Learning outcomes	Students know basic principles of Software Engineering. They are acquainted with an object-oriented programming language and can systematically develop and test software in the context of information and communication systems.
Requirements	none
Level	2. Semester
Type of module	Seminar, Laboratory Training
Status	Required module
Semesters when offered	Summer semester
Method of assessment / Type of examination	The method of assessment / type of examination must be defined by the lecturer within the deadline determined in §19 (2) RSPO. Should the deadline pass without determination of the form of assessment in the module, the following method of assessment / type of examination applies: SU Written examination (90 minutes), Ü Written laboratory report (10-15 pages) with consultation (15-30 minutes)
Grade assessment	See study and examination regulations
Content	• Fundamentals of object-oriented design and implementation with practical exercises in an object-oriented programming language, for example Python • Use of the Unified Modeling Language (UML) for expressing structure and interaction within larger software architectures • Basic knowledge of modern software engineering processes • Use of software development tools: Versioning systems, Integrated Development Environments (IDE), and Testing frameworks • Quality assurance in software-intensive systems • Basic design patterns, for example „Iterator“ or „Observer“ • Fundamental data structures, for example container classes, buffers, queues
Reading list	Sommerville: Software Engineering, Addison-Wesley Longman Gamma, Helm, Johnson, Vlissides: Patterns. Elements of Reusable Object-Oriented Software., Addison-Wesley Spillner, Linz, Schaefer: Software Testing Foundations - A Study Guide for the Certified Tester Exam, Rocky Nook Fowler: UML Distilled: A Brief Guide to the Standard Object Modeling Language, 3rd. Edition, Addison-Wesley
Further information	Language employed in the module: English
Required Room type	SU-Sem, Ü-Lab

Data field	Explanation
Module number	M09
German title / English title	Master-Kolloquium B / Master Colloquium B
Credits	5 ECTS
Workload	17 Contact hours (1 SWS Ü), 133 Hours of independent study
Subject coverage	Advanced interdisciplinary studies
Learning outcomes	Students have advanced knowledge in selected fields of information and communications technology, have an increased competence in the independent acquisition and classification of technical and scientific knowledge in professional practice and in the independent solving of current, practice-related and interdisciplinary problems, and have a solid competence in writing and presenting technical and scientific work results in English or German as a foreign language.
Requirements	none
Level	2. Semester
Type of module	Seminar, Project Work
Status	Required module
Semesters when offered	Summer semester
Method of assessment / Type of examination	The method of assessment / type of examination must be defined by the lecturer within the deadline determined in §19 (2) RSPO. Should the deadline pass without determination of the form of assessment in the module, the following method of assessment / type of examination applies: Project with report (10-15 pages) / Project Presentation (15 minutes)
Grade assessment	See study and examination regulations

Content	• Project work on a selected subject area under the supervision of a university lecturer
	  ○ Development of a case study, a theoretical approach or a practical solution focusing on a systematic approach to solving a problem using state-of-the-art scientific knowledge, and replicability of the results
	  ○ Discussion of current problems in information and communications engineering, preferably in an interdisciplinary context
	• Lectures and presentations of invited speakers on current selected topics in information and communications engineering
	• Written documentation and presentation of the work result

Reading list	Will be specified by the lecturers at the beginning of the course depending on project.
Further information	Language employed in the module: English or German
Required Room type	Ü-Sem

Data field	Explanation
Module number	M10
German title / English title	Studium Generale I / General Studies I
Credits	2,5 ECTS
Workload	34 Contact hours (2 SWS SU or 2 SWS Ü), 116 Hours of independent study
Subject coverage	Complementary general studies
Learning outcomes	The interdisciplinary content serves to complement the subject-specific studies and to realize the connections between society and its subsystems.
Requirements	none (exceptions may be defined for foreign languages)
Level	Bachelor and Master programs
Type of module	Seminar, exercises, lectures, role plays, text work, …… depending on selected course
Status	Required-elective module
Semesters when offered	every semester
Method of assessment / Type of examination	See description of selected course
Grade assessment	See study program
Content	In the engineering and natural sciences programs, learning contents from the fields of: • Political and social sciences • Arts and Humanities • Economic, legal and labor sciences • Foreign languages are to be incorporated. In the economic sciences programs, learning contents from the fields of: • Political and social sciences • Arts and Humanities • Natural sciences and engineering sciences • Foreign languages are to be incorporated.
Reading list	Will be specified in the descriptions of the selected course
Further information	The selection of the courses of this module is within the responsibility of the students themselves. The selection of the courses must be made by the students from the fields approved for their studies (see content above).
Required Room type	See descriptions of the selected course

Data field	Explanation
Module number	M11
German title / English title	Studium Generale II / General Studies II
Credits	2,5 ECTS
Workload	34 Contact hours (2 SWS SU or 2 SWS Ü), 116 Hours of independent study
Subject coverage	Complementary general studies
Learning outcomes	The interdisciplinary content serves to complement the subject-specific studies and to realize the connections between society and its subsystems.
Requirements	none (exceptions may be defined for foreign languages)
Level	Bachelor and Master programs
Type of module	Seminar, exercises, lectures, role plays, text work, …… depending on selected course
Status	Required-elective module
Semesters when offered	every semester
Method of assessment / Type of examination	See description of selected course
Grade assessment	See study program
Content	In the engineering and natural sciences programs, learning contents from the fields of: • Political and social sciences • Arts and Humanities • Economic, legal and labor sciences • Foreign languages are to be incorporated. In the economic sciences programs, learning contents from the fields of: • Political and social sciences • Arts and Humanities • Natural sciences and engineering sciences • Foreign languages are to be incorporated.
Reading list	Will be specified in the descriptions of the selected course
Further information	The selection of the courses of this module is within the responsibility of the students themselves. The selection of the courses must be made by the students from the fields approved for their studies (see content above).
Required Room type	See descriptions of the selected course

Data field	Explanation
Module number	M12
German title / English title	Wahlpflichtmodul III / Required-Elective Module III
Credits	5 LP
Workload	68 Contact hours (4 SWS Ü), 82 Hours of independent study
Subject coverage	Subject-specific specialization
Learning outcomes	See description of required-elective modules
Requirements	See description of required-elective modules
Level	2. Semester
Type of module	See description of required-elective modules
Status	See description of required-elective modules
Semesters when offered	Summer semester
Method of assessment / Type of examination	See description of required-elective modules
Grade assessment	See description of required-elective modules
Content	Selected subjects depending on selected module from the catalog of required-elective modules For this required-elective module, modules WP01 to WP08 can be selected from the catalog of required-elective modules.
Reading list	See description of required-elective modules
Further information	• The Faculty Council of Faculty VII may decide to provide additional modules as required-elective modules. This decision will be taken before the beginning of the Semester. • Upon application, students may also select a module from another master program at the Beuth-Hochschule für Technik Berlin as required-elective module in the second curriculum semester, provided that the content does not correspond to the required modules of their own study program. The Dean of the Faculty VII decides on the application. • In case of a temporary study abroad, the modules completed there can be fully accredited as required-elective modules, provided that the content does not correspond to the required modules of their own study program. Accrediting will be decided by the Dean of the Faculty VII.
Required Room type	See description of required-elective modules

Data field	Explanation
Module number	M13
German title / English title	Wahlpflichtmodul IV / Required-Elective Module IV
Credits	5 LP
Workload	68 Contact hours (4 SWS Ü), 82 Hours of independent study
Subject coverage	Subject-specific specialization
Learning outcomes	See description of required-elective modules
Requirements	See description of required-elective modules
Level	2. Semester
Type of module	See description of required-elective modules
Status	See description of required-elective modules
Semesters when offered	Summer semester
Method of assessment / Type of examination	See description of required-elective modules
Grade assessment	See description of required-elective modules
Content	Selected subjects depending on selected module from the catalog of required-elective modules For this required-elective module, modules WP01 to WP08 can be selected from the catalog of required-elective modules.
Reading list	See description of required-elective modules
Further information	• The Faculty Council of Faculty VII may decide to provide additional modules as required-elective modules. This decision will be taken before the beginning of the Semester. • Upon application, students may also select a module from another master program at the Beuth-Hochschule für Technik Berlin as required-elective module in the second curriculum semester, provided that the content does not correspond to the required modules of their own study program. The Dean of the Faculty VII decides on the application. • In case of a temporary study abroad, the modules completed there can be fully accredited as required-elective modules, provided that the content does not correspond to the required modules of their own study program. Accrediting will be decided by the Dean of the Faculty VII.
Required Room type	See description of required-elective modules

Data field	Explanation
Module number	M14
German title / English title	Abschlussprüfung / Final Examination Module 1. Master-Arbeit / Master's Thesis 2. Mündliche Abschlussprüfung / Oral Final Examination (Final examination according to latest version of the study and examination regulations, RSPO)
Credits	30 ECTS
Workload	900 hours
Subject coverage	Subject-specific specialization
Learning outcomes	Master's Thesis Independent engineering of an ambitious scientific project with written elaboration, including German and / or English summary Oral final examination The oral final examination is oriented towards the subject fields of the thesis as well as towards the content of the Master's program. The aim of the final examination is to determine whether the student has got methodological knowledge in the subject fields of the Master's program, which enables him / her to work scientifically in this area, and whether he / she is able to critically challenge the results of the thesis in a larger subject-specific context.
Requirements	Admission according to latest version of the RSPO
Level	3. Semester
Type of module	Master's Thesis Scientific work, supervised according to § 29 (7) RSPO by the supervisor of the Master's thesis. Oral final examination Presentation /oral examination
Status	Required module
Semesters when offered	Every semester
Method of assessment / Type of examination	Master's Thesis Duration of work: 5 months according to §6 Study and Examination Regulations Written elaboration (60-100 pages) Oral final examination Presentation (ca. 15 minutes) and oral examination (30-45 minutes)
Grade assessment	Assessment of the final examination by the board of examiners
Content	Master's Thesis Solution of practice-oriented problems using scientific methods Oral Final Examination Presentation and defense of the Master's thesis and its results in a critical discussion; presentation techniques
Reading list	Subject-specific
Further information	Oral Final Examination

	If agreed upon by examinee and board of examiners the oral final examination can take place in German.

Data field	Explanation
Module number	WP01
German title / English title	Digitale Funksysteme / Digital Radio Systems
Credits	5 ECTS
Workload	68 Contact hours (4 SWS Ü), 82 Hours of independent study
Subject coverage	Subject-Specific Specialization
Learning outcomes	Students understand the behavior of the mobile radio channel in LOS and NLOS multipath environments, as well as the most important transmission techniques used in modern spectrally efficient digital radio systems. They know how these techniques are applied to modern radio standards as i. e. LTE, WLAN and broadcast systems. Moreover, they have advanced practical experience in simulating and experimentally investigating digital radio systems.
Requirements	none
Level	1./2. Semester
Type of module	Seminar, Laboratory Training
Status	Required-Elective Module
Semesters when offered	Every semester
Method of assessment / Type of examination	The method of assessment / type of examination must be defined by the lecturer within the deadline determined in §19 (2) RSPO. Should the deadline pass without determination of the form of assessment in the module, the following method of assessment / type of examination applies: 80% Written examination (90 minutes), 20% Project Presentation (30 minutes)
Grade assessment	See study and examination regulations
Content	• Introduction to digital radio systems and networks • Typical functional blocks of a digital radio system, mathematical system description for SISO case • Compendium of fundamental propagation effects in mobile radio channels • Description of the mobile radio channel in multipath environments for NLOS (Rayleigh fading) and LOS/NLOS (Rician fading) case • Radio channel characterization by power delay profile, delay spread, coherence bandwidth, Doppler spread and coherence time • Multiple Antenna Systems: mathematical fundamentals (matrix algebra, eigenvalues, SVD), system configurations, system description for MIMO case, diversity processing, spatial multiplexing, MIMO capacity • Digital radio systems based on OFDM/OFDMA and SC-FDMA • Application of before-mentioned techniques to modern radio standards i. e. LTE, WLAN and broadcast systems • System simulations investigating the mobile radio channel • Lab projects dealing with advanced SDR-based experimentation of i. e. high-order-QAM-, OFDM- or MIMO-transmission • Projects dealing with theoretical research of detailed aspects of cutting-edge radio standards as i. e. LTE-A and 5G
Reading list	Cox: Introduction to LTE, Wiley Dahlman: 4G LTE / LTE-Advanced for Mobile Broadband, Academic Press Kammeyer: Nachrichtenübertragung, Vieweg Nuszkowski: Digitale Signalübertragung im Mobilfunk
Further information	Language employed in the module: English
Required Room type	Ü-Sem, Ü-Lab

Data field	Explanation
Module number	WP02
German title / English title	Modellbasierter Entwurf digitaler Kommunikationssysteme / Model-Based Digital Communication Systems Design
Credits	5 ECTS
Workload	68 Contact hours (4 SWS Ü), 82 Hours of independent study
Subject coverage	Subject-Specific Specialization
Learning outcomes	Students know the fundamentals of fast and efficient digital signal processing in digital communication systems. They have got an overview about typical devices and architectures for implementing such signal processing and master the integration and the embedding of hardware and software in versatile prototype systems using a model-based approach and automatic code generation. They can design, simulate and verify signal processing algorithms and apply their knowledge in state-of-the-art platforms for communication systems, e.g. for computer vision or software defined radio (SDR).
Requirements	Recommendation: Basic knowledge in digital and microprocessor technology, digital communication systems and signal processing
Level	1./2. Semester
Type of module	Seminar, Laboratory Training
Status	Required-Elective module
Semesters when offered	Every semester
Method of assessment / Type of examination	The method of assessment / type of examination must be defined by the lecturer within the deadline determined in §19 (2) RSPO. Should the deadline pass without determination of the form of assessment in the module, the following method of assessment / type of examination applies: 50% Written examination (90 minutes), 50% Written laboratory report (10-15 pages) of the laboratory group with consultation (15-30 minutes)
Grade assessment	See study and examination regulations
Content	• Fundamentals of fast and efficient digital signal processing (number representation, pipelining, adder trees, distributed arithmetic, CORDIC architectures, …) • Devices and architectures for fast and efficient signal processing in digital communication systems (General Purpose Processors, DSP, FPGA, HW accelerators, bus architectures) • Integration and embedding hard- and software in versatile prototype systems using a model based approach and automatic code generation • Design of DSP algorithms, simulation of the hardware, generation of C or HDL code and verification in model based prototype systems
Reading list	U. Meyer-Baese: Digital Signal Processing with Field Programmable Gate Arrays, Springer E. Gryver: Implementing Software Defined Radio, Springer S. Pollin, M. Timmers, L. van der Perre: Software Defined Radios – From Smart(er) to Cognitive, Springer
Further information	Language employed in the module: English
Required Room type	Ü-Sem, Ü-Lab

Data field	Explanation
Module number	WP03
German title / English title	Network Sicherheit und Kryptografie / Network Security and Cryptography
Credits	5 ECTS
Workload	68 Contact hours (4 SWS Ü), 82 Hours of independent study
Subject coverage	Subject-specific specialization
Learning outcomes	Students understand the mathematical properties of secure algorithms and protocols. This includes modular arithmetic, finite-field arithmetic and properties of Euler's totient function. They are able to evaluate properties of current encryption methods and hash-functions. They know about network protection mechanisms such as firewalls, Virtual Private Networks and have practical experience in implementing security mechanisms in IP-networks. They can evaluate the security thread-level of networked environments and are able to assess and implement necessary protection measures.
Requirements	-
Level	1./2. Semester
Type of module	Seminar, Laboratory Training
Status	Required-elective module
Semesters when offered	Every semester
Method of assessment / Type of examination	The method of assessment / type of examination must be defined by the lecturer within the deadline determined in §19 (2) RSPO. Should the deadline pass without determination of the form of assessment in the module, the following method of assessment / type of examination applies: Written examination (120 minutes)
Grade assessment	See study and examination regulations
Content	• Properties of historical and modern crypto-systems • Mathematical foundations of cryptographic methods • Symmetric and asymmetric encryption algorithms • Approaches for the generation of random-numbers • Hash-functions and Message Authentication Codes (HMAC) • Digital Signatures • Cryptographic protocols for key-exchange and authentication • Denial of Service Attacks (DoS) and Distributed Denial of Service (DDoS) • Modelling and properties of security protocols (using TLS as an example) • Protecting Data and Privacy: authentication and access control • Firewalls: packet-filter und application-level-gateways • Virtual Private Networks based on Layer-3 encryption (IPsec) • Exemplary use of RSA, AES and Diffie-Hellman Key-Exchange • Introduction to firewalls (packet-filter) • Classroom discussion and presentations of scientific papers/methods relevant to the field
Reading list	W. Stallings: Cryptography and Network Security, Prentice Hall Bruce Schneier: Applied Cryptography, Pearson-Studium
Further information	Language employed in the module: English
Required Room type	Ü-Sem, Ü-Lab

Data field	Explanation
Module number	WP04
German title / English title	Fortgeschrittene Methoden des Switching und Routing / Advanced Switching and Routing
Credits	5 ECTS
Workload	68 Contact hours (4 SWS Ü), 82 Hours of independent study
Subject coverage	Subject-specific specialization
Learning outcomes	Students know algorithms that perform shortest and optimal-path computations in multi-hop-networks. They understand roles, functions and design-principles of network-elements. They have a firm grasp on basic principles of network formation, the role of subnetting and the creation hierarchical network architectures. They can create and implement addressing plans (both for IPv4 and IPv6). They have a working knowledge in the configuration and troubleshooting of small and medium-sized network installations and understand methods of traffic-engineering in IP und Ethernet networks.
Requirements	none
Level	1./2. Semester
Type of module	Seminar, Laboratory Training
Status	Required-elective module
Semesters when offered	Every semester
Method of assessment / Type of examination	The method of assessment / type of examination must be defined by the lecturer within the deadline determined in §19 (2) RSPO. Should the deadline pass without determination of the form of assessment in the module, the following method of assessment / type of examination applies: Written examination (120 minutes)
Grade assessment	See study and examination regulations

Content	• Routing-algorithms for different network architectures (RIP, OSPF, BGP)
	• Hard- and Software-architectures of modern routers and switches
	  ○ Content-Addressable Memory
	  ○ Fast-Path/Slow-Path,
	  ○ Data-/Control-/Management plane
	• Internet Architectural Model (peering, transit, Internet Exchanges)
	• QoS-mechanisms for guaranteed network performance
	• Traffic modelling in packet-switched networks
	• Multicast
	  ○ Protocols for local group management (IGMP)
	  ○ Multicast routing and distribution (PIM)
	• Routing und Switching in LAN- und MAN-Networks
	  ○ Network Address Translation
	  ○ Multi-Protocol Label Switching (MPLS)
	  ○ Traffic Engineering
	• Hands-on configuration of network infrastructures based on Cisco-routers
	  ○ RIP, OSPF, BGP
	  ○ Route-Redistribution
	• Configuration of QoS features such as Diffserv packet-marking and prioritisation of traffic-classes for multimedia data
	• Construction of routable IPv6 networks and virtualised network architectures (VLAN, SDN)

Reading list	D Medhi, K. Ramasamy: Network Routing, Morgan Kaufmann Andrew S. Tanenbaum: Computer Networks. Pearson Studium J. Kurose und K. Ross: Computer Networking. Pearson Studium
Further information	Language employed in the module: English
Required Room type	Ü-Sem, Ü-Lab

Data field	Explanation
Module number	WP05
German title / English title	Photonische Kommunikationssysteme / Photonic Communication Systems
Credits	5 ECTS
Workload	68 Contact hours (4 SWS Ü), 82 Hours of independent study
Subject coverage	subject-specific specialization
Learning outcomes	Students • know the function of important photonic systems with their components and subsystems and the basic parameters with impact on the system performance • are aware of the latest developments and trends in the field of photonic communication systems • have deepened their knowledge in tailored laboratory exercises • are able to design a photonic communication system and do a principal part of system engineering by using a professional simulation tool
Requirements	recommendation: Advanced Signal Transmission Techniques (1st sem.), basic knowledge about optical communications engineering
Level	1./2. semester
Type of module	Seminar, Laboratory training
Status	Required-elective module
Semesters when offered	Every semester
Method of assessment / Type of examination	The method of assessment / type of examination must be defined by the lecturer within the deadline determined in §19 (2) RSPO. Should the deadline pass without determination of the form of assessment in the module, the following method of assessment / type of examination applies: 50% Written examination (90 minutes), 50% Written laboratory report (10-15 pages) of the laboratory group with consultation (15-30 minutes)
Grade assessment	see study and examination regulations
Content	• introduction to fiber optic communication systems • concepts and architectures of optical transmitters • concepts and architectures of optical receivers • transmission channel: impairments and their compensation • characterization of system performance • laboratory exercise: use a standard simulation tool to deepen and enhance the understanding for the topics taught in the seminar
Reading list	Noé: Essentials of Modern Optical Fiber Communication, Springer 2016 Kumar, Deen: Fiber Optic Communications, Wiley 2014 Voges, Petermann: Optische Kommunikationstechnik, Springer 2014 Kaminow, Lee, Willner (Editors): Optical Fiber Telecommunications, VIA: Components and Subsystems, Academic Press 2013 Kaminow, Lee, Willner (Editors): Optical Fiber Telecommunications, VIB: Systems and Networks, Academic Press 2013 Werner: Nachrichtentechnik, Vieweg und Teubner 2010 Seimetz: High-Order Modulation for Optical Fiber Transmission, Springer 2009
Further information	Language employed in the module: English
Required Room type	Ü-Sem, Ü-Lab

Data field	Explanation
Module number	WP06
German title / English title	Multimedia-Rundfunksysteme / Multimedia Broadcast Systems
Credits	5 ECTS
Workload	68 Contact hours (4 SWS Ü), 82 Hours of independent study
Subject coverage	Subject-Specific Specialization
Learning outcomes	Students know the fundamentals of audio and video signals and multimedia coding for broadcast systems; how to measure quality of coded multimedia signals; and fundamentals of broadcast systems and current standards. They can apply the knowledge in simulating coding methods and implementing and configuring broadcasting systems.
Requirements	Recommendation: Basic knowledge in digital communication systems and signal processing
Level	1./2. Semester
Type of module	Seminar, Laboratory Training
Status	Required-Elective module
Semesters when offered	Every semester
Method of assessment / Type of examination	The method of assessment / type of examination must be defined by the lecturer within the deadline determined in §19 (2) RSPO. Should the deadline pass without determination of the form of assessment in the module, the following method of assessment / type of examination applies: 50% Written examination (90 minutes), 50% Written laboratory report (10-15 pages) of the laboratory group with consultation (15-30 minutes)
Grade assessment	See study and examination regulations
Content	• Analog and digital audio and video signals • Audio and video transport and coding for broadcasting systems (MPEG, H264.x, Dolby Digital) • Audio and video quality analysis • Digital audio broadcasting standards (DAB(+), DRM(+) and others) • Digital video broadcasting standards (DVB-T/C/Sx and others) • Internet radio and IP-TV • Multimedia Broadcast Multicast in 3-5G Mobile Communication Systems • Lab training including selected topics in audio and video coding, setup and configuration of a broadcast system, measurements in broadcast systems
Reading list	W. Fischer: Digital Video and Audio Broadcasting Technology, Springer M. Wien: High Efficiency Video Coding, Springer M. Bosi, R. Goldberg: Introduction to Digital Audio Coding and Standards, Springer
Further information	Language employed in the module: English
Required Room type	Ü-Sem, Ü-Lab

Data field	Explanation
Module number	WP07
German title / English title	Maschinelles Lernen / Machine Learning
Credits	5 ECTS
Workload	68 Contact hours (4 SWS Ü),82 Hours of independent study
Subject coverage	Subject-specific specialization
Learning outcomes	Students have an overview of machine learning methods and can assess their usability for a certain application. They can implement simple machine learning solutions using freely available software tools.
Requirements	none
Level	1./2. Semester
Type of module	Seminar, Laboratory Training
Status	Required-Elective module
Semesters when offered	Every semester
Method of assessment / Type of examination	The method of assessment / type of examination must be defined by the lecturer within the deadline determined in §19 (2) RSPO. Should the deadline pass without determination of the form of assessment in the module, the following method of assessment / type of examination applies: 50% Written examination (90 minutes), 50% Written laboratory report (10-15 pages) of the laboratory group with consultation (15-30 minutes)
Grade assessment	See study and examination regulations
Content	• Review of mathematical foundations • Overview of machine learning methods and applications • Linear regression • K-means clustering • Neural networks • Hidden Markov models • Freely available machine learning software tools
Reading list	Haykin: Neural Networks and Learning Machines, Prentice Hall International.
Further information	Language employed in the module: English
Required Room type	Ü-Sem, Ü-Lab

Data field	Explanation
Module number	WP08
German title / English title	Verteilte Systeme und Dienste / Distributed Systems and Services
Credits	5 ECTS
Workload	68 Contact hours (4 SWS Ü), 82 Hours of independent study
Subject coverage	Subject-specific specialization
Learning outcomes	Students understand fundamental properties of distributed systems relevant to the design and implementation of communication systems. They know standard design patterns for distributed systems and can design and build software that makes optimal use of features offered by operating systems and network protocols. The students understand current trends in distributed systems research and standardisation.
Requirements	none
Level	1./2. Semester
Type of module	Seminar, Laboratory Training
Status	Required-elective module
Semesters when offered	Every semester
Method of assessment / Type of examination	The method of assessment / type of examination must be defined by the lecturer within the deadline determined in §19 (2) RSPO. Should the deadline pass without determination of the form of assessment in the module, the following method of assessment / type of examination applies: 50% Written examination (90 minutes), 50% Written laboratory report (10-15 pages) of the laboratory group with consultation (15-30 minutes)
Grade assessment	See study and examination regulations
Content	• Foundation of operating systems: resource-management, process abstraction and life-cycle, scheduling mechanisms • Foundation of communication systems: Two-Army-Problem, principal properties of communication channels, network transport protocols • Inter-process communication: signals, shared memory, pipes, sockets • Understand typical issues in distributed systems: error-cases, synchronisation, distributed time-base and event mechanisms • Socket-programming in Java and C • Properties of low-power wireless networks such as 802.15.4 • Communication Architectures: Client/Server, Publish/Subscribe, P2P • Middleware-Architectures: Remote Procedure Calls (RPC) and application protocols: (HTTP, HTML, XML, JSON) • Exemplary distributed architectures: DNS & Web • Designing RESTful services with AJAX and JSON • Design of application scenarios for wireless sensor networks • Using the Contiki-OS for 8/16/32-bit microcontrollers • Analysis of use cases for communication protocols (real-time communication, management of limited resources, energy efficiency, excessive packet drop, secure deployment and operation)
Reading list	A. Tanenbaum, M. van Steen: Distributed Systems, Prentice-Hall G. Bengel: Grundkurs Verteilte Systeme, Springer Vieweg R. Stevens, S. Rago: Advanced Programming in the UNIX Environment, Addison-Wesley
Further information	Language employed in the module: English
Required Room type	Ü-Sem, Ü-Lab