Universitatea Naţională de Ştiinţă şi Tehnologie Politehnica Bucureşti
Facultatea de Electronică, Telecomunicaţii şi
Tehnologia Informaţiei

COURSE DESCRIPTION

1. Program identification information

1.1 Higher education institution	**National University of Science and Technology Politehnica Bucharest**
1.2 Faculty	**Electronics, Telecommunications and Information Technology**
1.3 Department	**Telecommunications**
1.4 Domain of studies	Electronic Engineering, Telecommunications and Information Technology
1.5 Cycle of studies	Masters
1.6 Programme of studies	Advanced Software Technologies for Communications

2. Date despre disciplină

2.1 Course name (ro) (en)				Arhitecturi pentru reţele şi servicii Architectures for Networks and Services			
2.2 Course Lecturer				Prof. Dr. Eugen Borcoci			
2.3 Instructor for practical activities				Conf.dr Octavian Catrina			
2.4 Year of studies	1	2.5 Semester	1	2.6. Evaluation type	E	2.7 Course regime	Ob
2.8 Course type		S	2.9 Course code	1		2.10 Tipul de notare	Nota

3. Total estimated time (hours per semester for academic activities)

3.1 Number of hours per week	5	Out of which: 3.2 course	3	3.3 seminary/laboratory	2
3.4 Total hours in the curricula	70	Out of which: 3.5 course	42	3.6 seminary/laboratory	28
Distribution of time:					hours
Study according to the manual, course support, bibliography and hand notes Supplemental documentation (library, electronic access resources, in the field, etc) Preparation for practical activities, homework, essays, portfolios, etc.					70
Tutoring					0
Examinations					10
Other activities (if any):					0

3.7 Total hours of individual study	80.00
3.8 Total hours per semester	150
3.9 Number of ECTS credit points	6

4. Prerequisites (if applicable) (where applicable)

4.1 Curriculum	Course on telecommunications networks in the undergraduate program that includestheTCP/IP protocol stack.. Computer architecture, Data Communications, Architecturesand Communications protocols, Prgrammimg languages, Operating systems, Data bases,Networks and services
4.2 Results of learning	Basic knowledge of telecommunications networks: principles, architectures and protocols,especially the TCP/IP protocol stack used in the Internet.

5. Necessary conditions for the optimal development of teaching activities (where applicable)

5.1 Course	Lecture hall equipped with video projector, screen, blackboard/whiteboard.
5.2 Seminary/ Laboratory/Project	Laboratory equipped with computers with Windows (or Linux) operating systemandvideo projector. The network emulator GNS3 and the protocol analyzer Wiresharkare free.

6. General objective *(Reffering to the teachers' intentions for students and to what the students will be thought during the course. It offers an idea on the position of course in the scientific domain, as well as the role it has for the study programme. The course topics, the justification of including the course in the currcula of the study programme, etc. will be described in a general manner)*

The course offers advanced knowledge on architectures and protocols used in telecom and computernetworks.It extends the basic knowledge obtained in the bachelor courses, complementing other specific courses in TSAC specialization.

7. Competences *(Proven capacity to use knowledge, aptitudes and personal, social and/or methodological abilities in work or study situations and for personal and proffesional growth. They refflect the empolyers requirements.)*

Specific Competences	Multiple plane architectures. Description, analysis and explaination of the thearchitecture and the operation of networks and services based on standard technologiesand protocols used in the Internet and telecom mobile networks., Knlowledge on noveltechnologies like SDN, NFV, 4G, 5G, IoT, IoV, Cloud/Edge/Fog computing, AI/MLfor networks and services.
Transversal (General) Competences	Analysis of the problems encountered in the field of networks an services identifyingthe elements for which there are established solutions, and thus ensuring the fulfillmentof professional tasks. Ability to adapt to new technologies and to document forprofessional and personal development, through continuous training.Ability to reasonusing scientific concepts and domain specific terminology, to independently exploreand analyze information, as well as to find and present conclusions and/or solutions.

8. Learning outcomes *(Synthetic descriptions for what a student will be capable of doing or showing at the completion of a course. The learning outcomes reflect the student's acomplishments and to a lesser extent the teachers' intentions. The learning outcomes inform the students of what is expected from them with respect to performance and to obtain the desired grades and ECTS points. They are defined in concise terms, using verbs similar to the examples below and indicate what will be required for evaluation. The learning outcomes will be formulated so that the correlation with the competences defined in section 7 is highlighted.)*

Knowledge	*The result of knowledge aquisition through learning. The knowledge represents the totality of facts, priciples, theories and practices for a given work or study field. They can be theoretical and/or factual.* Capabilities to apply knowledge on network architectures and services in different specific cases ofsystems for fixed and mobile communications. All development phases can be supported: requirements, business model, architectural specification, system design, implementation and integration.

Skills	*The capacity to apply the knowledge and use the know-how for completing tasks and solving problems. The skills are described as being cognitive (requiring the use of logical, intuitive and creative thinking) or practical (implying manual dexterity and the use of methods, materials, tools and intrumentation).* Identifies and formulates the basic functional requirements of telecommunications and computer networks. Analyzes, describes and explains the purpose and operation of the main components of a network (devices, protocols), using specific terminology. Development of systems using novel technologies like SDN, NFV, 4G, 5G, IoT, IoV, Cloud/Edge/Fog computing, AI/ML for networks and services.
Responsability and autonomy	*The student's capacity to autonomously and responsably apply their knowledge and skills.* Selects and understands relevant bibliographic sources. - Observes the principles of academic ethics, such as correctly citing the bibliographic sources. - Demonstrates responsiveness to new learning contexts. - Collaborates with colleagues and instructors during the teaching activities. - Demonstrates autonomy in organizing the learning situation or in solving problems. - Realizes the value of his contribution in the field of engineering to the identification of viableandsustainable solutions to solve problems in social and economic life (social responsibility). - Analyzes and capitalizes on business/entrepreneurial opportunities in the specialization field. - Demonstrates management skills real-life situations.

9. Teaching techniques *(Student centric techniques will be considered. The means for students to participate in defining their own study path, the identification of eventual fallbacks and the remedial measures that will be adopted in those cases will be described.)*

The general teaching process will use both expository (lecture) and conversational-interactive teaching methods, based on discovery learning models facilitated by direct and indirect exploration (experiment, demonstration, modeling), but also using action-based methods, such as exercise, hands-on activities and problem-solving. The lectures activity uses mixed (text and figures) presentations to facilitate understanding information. Each lecture will revisit shortly the previous material linked with the current one.

In the lab, the students build and configure using an emulator examples of networks and systems that are small-scale models of the networks and systems used in the integrated networks. The students will perform experiments that allow them to examine and analyze the evolution of the state of each device and the interactions between them (e.g., the discovery of destinations and routes in IP-based networks,

Moodle and Teams platforms will provide lecture and lab notes and documents and support exposures.

10. Contents

COURSE		
Chapter	**Content**	**No. hours**
1	1. Multiple plane architectural concepts for networks and services : Data Plane ;Control plane; Management plane. Integration of the architectural planes. Business models-examples. SLA contracts. Examples of architectures MPLS, 4G, 5G, NGN, Cloud/Fog/Edge, Internet of Things, Vehicular internet (IoV), Virtualization technologies, SDN, NFV.	12
2	Revision of the architectures for mobile communication wide area networks : 2G,2.5G, 3G.	3

3	4G/LTE architectures and systems. General architecture. Addressing schemes. Access and core network, IP-based mobility. User and control plane protocols. Hierarchical channel structures. PHY level elements.	9
4	Software defined networking,(SDN). General concepts, applications and services, usecases. Architecture. Flow processing in the control plane. Openflow, protocol . Managementand configuration. Controllers: RYU< ONOS, ONOS, etc. Scalability issues.	9
5	Network Function Virtualisation (NFV) Concepts, Architectural ref. model ETSI. Use cases and applications.	3
6	5G networks. Applications and services. Architecture. Slicing concepts. SDN and NFV in 5G. Multi-domain virtual networks. AI/ML technologies in 5G.	6
7	Annexes. Complemntary material on layered architecures, MPLS, tunnelingtechniques. LAN, MAN, WAN standards. LTE PHY channels. Virtualisation exemples.	0
	Total:	42

Bibliography:

Curs ARS Moodle: https://curs.upb.ro/2024/
[1] Andrew Tanenbaum. Computer Networks. 4th ed. Prentice Hall, 2003, (Andrew Tanenbaum. Reteledecalculatoare. Ed. a 4-a. Editura BYBLOS, 2003).
[2]Peter Mell , Timothy Grance, The NIST Definition of Cloud Computing, Special Publication 800-145,Recommendations of the National Institute of Standards and Technology , 2011
[3]Fang Liu, Jin Tong, Jian Mao, Robert Bohn, John Messina, Lee Badger and DawnLeaf,Recommendations of the National Institute of Standards and Technology, NIST "CloudComputingReference Architecture", Special Publication 500-292 , 2011
[4]Larry Peterson, Bruce Davie. Computer Networks. A systems approach. 4th ed. MorganKaufmann,2007.
[5]ITU-T Rec. Y.2011, "General Principles and General Reference Model for Next Generation Network."
[6]M.Mendonca, et. al., A Survey of Software-Defined Networking: Past, Present,and FutureofProgrammable Networks, http://hal.inria.fr/hal-00825087/
[7]S. H.Yeganeh, et.al., On Scalability of Software-Defined Networking, IEEE Comm.Magazine,February 2013.
[8]ONF 2014 OF---CONFIG 1.2 OpenFlow Management and Configuration Protocol
[9]ETSI GS NFV 002 v1.2.1 2014-12, NFV Architectural Framework
[10]ONF, "OpenFlow-Enabled SDN and NetworkFunctionsVirtualisation,"https://www.opennetworking.org/images/stories/downloads/sdn-resources/solutionbriefs/sb-sdn-nvf-solution.pdf
[11]R,Khan et al., "Future Internet: The Internet of Things Architecture, Possible Applications andKeyChallenges", Dec. 2012, https://www.researchgate.net/publication/261311447
[12]ONF TS-025 OpenFlow Switch Specification, Version 1.5.1 (Protocol version 0x06), 2015
[13]ETSI TS 136 300 V8.9.0 (2009-07), LTE; Evolved Universal Terrestrial Radio Access (E-UTRA)andEvolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall description; Stage 2 (3GPPTS36.300 version 8.9.0 Release 8)
[14]"LTE Tutorial", http://www.tutorialspoint.com/lte
[15]Introduction to Mobile IPv6, IIS5711: Mobile Computing Mobile Computing andBroadbandNetworking Laboratory CIS, NCTU, www.item.ntnu.no/fag/tm8100/Pensumstoff2004/mipv6-bra.ppt
[16]Karim El Malki, Mobile IPv6 Tutorial, EricssonAB,http://www.usipv6.com/ppt/MobileIPv6_tutorial_SanDiegok.pdf, 2003
[17]Peter R. Egli , PROXY MOBILE IPV6, INDIGOO.COM, www.slideshare.net/PeterREgli/p-6098167
[18]S. Gundavelli et al., RFC 5213, Proxy Mobile IPv6, 2008, www.ietf.org
[19]Ghassan A. Abed Mahamod Ismail Kasmiran Jumari, "The Evolution to 4G CellularSystems:Architecture and Key Features of LTE-Advanced Networks", IRACST – International JournalofComputer Networks and Wireless Communications (IJCNWC), ISSN: 2250-3501Vol. 2, No. 1, 2012
[20] 3GPP M.Nohrborg, LTE vOverview http://www.3gpp.org/technologies/keywords-acronyms/98-lte
[21]Ghassan A. , Abed Mahamod, Ismail Kasmiran Jumari, "The Evolution to 4G CellularSystems:Architecture and Key Features of LTE-Advanced Networks", IRACST – International JournalofComputer Networks and Wireless Communications (IJCNWC), ISSN: 2250-3501, Vol. 2, No. 1, 2012
[22] Arpit Joshipura, Mobile Broadband driven by Convergence of IP and LTE technologies,Ericsson,2011, http://www.comsocscv.org/docs/Talk_111109_MobileBroadband.pdf
[23] Keysight Technologies " LTE-Advanced: Technology and Test Challenges 3GPP Releases 10, 11,12and Beyond", http://literature.cdn.keysight.com/litweb/pdf/5990-6706EN.pdf

[24] J. Ordonez-Lucena, et al., "Network Slicing for 5G with SDN/NFV: Concepts, ArchitecturesandChallenges", IEEE Communications Magazine, 2017, Citation information:DOI10.1109/MCOM.2017.1600935

LABORATORY

Crt. no.	Content	No. hours
1	Intra-domain routing using OSPF. Experimental study of routing using the OSPF protocol.	2
2	Inter-domain routing in the Internet. Experimental study of network interconnection using the BGP protocol.	2
3	MPLS networks. Experimental study of the implementation and operation of network interconnection services using BGP and MPLS.	2
4	Layer 3 virtual private networks (VPN) based on MPLS and BGP. Experimental study of the implementation and operation of VPN services using MPLS and BGP.	2
5	MPLS TE (Traffic Engineering) - Part 1. Experimental study of MPLS TE tunnel setup using RSVP-TE (Resource Reservation Protocol) and OSPF-TE.	2
6	MPLS TE (Traffic Engineering) - Part 2. Experimental study of the operation of MPLS-TE tunnels: tunnel priority, admission control, tunnel restoration after failures.	2
7	Seminary and lab test.	0
	Total:	14

SEMINARY

Crt. no.	Content	No. hours
1	Intra-domain routing in the Internet. RIP and OSPF routing protocols.	2
2	Inter-domain routing in the Internet. BGP routing protocol. Policy-based routing.Network interconnection using BGP.	2
3	MPLS networks. MPLS (Multi-Protocol Label Switching) and LDP (Label Distribution Protocol) protocols. Network interconnection using the MPLS and BGP protocols.	2
4	Virtual Private Network (VPN) services. Layer 3 VPN services based on the MPLS and BGP protocols.	2
5	MPLS TE (Traffic Engineering) - Part 1. MPLS TE tunnels set up using RSVP-TE (Resource Reservation Protocol) and OSPF-TE protocols.	2
6	MPLS TE (Traffic Engineering) - Part 2. Tunnel priority, admission control, tunnel restoration after breakdowns, etc.	2
7	Review for seminary and lab test.	2
	Total:	14

Bibliography:

1. Octavian Catrina. Architectures for networks and services. Lab descriptions (PDF) and PowerPointpresentations on the Moodle platform:
https://curs.upb.ro/
2. L. Peterson, B. Davie. Computer Networks. A systems approach. Ediția 6, 2019, available online:
https://www.systemsapproach.org/
3. Luc De Ghein. MPLS Fundamentals. Cisco Press, 2006.

11. Evaluation

Activity type	11.1 Evaluation criteria	11.2 Evaluation methods	11.3 Percentage of final grade
11.4 Course	Knowledge at advanced level onarchitectures, for systems,technologies and protocolspresented in the lectures.	Written exam	50%
	Interactive participation to lectures		10%
11.5 Seminary/laboratory/project	The ability to set up, test, analyze and debug networks and services that use the protocols studied in the seminary and laboratory.	Test based on the cases studies and experiments in the seminary and laboratory.	40%
11.6 Passing conditions			
Min. 20 points out of 40 for lab. Total 50% out of 100% for passing.			

12. Corroborate the content of the course with the expectations of representatives of employers and representative professional associations in the field of the program, as well as with the current state of knowledge in the scientific field approached and practices in higher education institutions in the European Higher Education Area (EHEA)

The course offers professional bases for engineers who perform research, design, development, maintenanceand exploitation of systems and advanced technologies in integrated telecom and computer networks , for alarge range of applications and services.

Date	Course lecturer	Instructor(s) for practical activities
25.09.2025	Prof. Dr. Eugen Borcoci	Conf.dr.Octavian Catrina

Date of department approval	Head of department
26.09.2025	Conf. Dr. Serban Georgica Obreja

Date of approval in the Faculty Council	Dean
26.09.2025	Prof. Dr. Mihnea Udrea

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