UAB
Universitat Autònoma de Barcelona

Telecommunications Networks

2026/2027

Code: 102699
Credits: 6

Degree programme	Type	Course
Telecommunication Systems Engineering	OB	3

Contact lecturer

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Teaching staff (external to UAB)

Josep Xavier Salvat

Pere Camps

Group languages

You can consult this information at the end of the document.

Prerequisites

To follow the "Telecommunication Networks" course with guarantees, the students must have taken and passed the following courses:

- Statistics
- Foundations of Networks

Objectives

The aim of the course is to understand the technological evolution and the architecture of telecommunication networks, as well as the problems that arise and the solutions that exist in the process of designing and exploiting them. Therefore, once the course is over, students must be able to:

- Know the taxonomy, technological evolution and architecture of telecommunication networks
- Know the mathematical tools that allow to model the operation of a system and how to apply them to the dimensioning of a telecommunication network
- Describe the requirements of a telecommunication network regarding the quality of service and know the techniques used to implement it
- Describe the problem of network congestion and know the operating principles of the mechanisms that exist to solve it
- Describe the need of network interconnection and know the operation of the protocols that are used on the Internet
- Describe the concept of network control and management, and know the operation of the protocols that are used on the Internet

Learning outcomes

1. Develop critical thinking and reasoning.
2. Develop the capacity for analysis and synthesis.
3. Develop scientific thinking.
4. Work autonomously.
5. Develop independent learning strategies.
6. Manage available time and resources.
7. Critically evaluate the work done.
8. Work cooperatively.
9. Assume and respect the role of the different members of a team, as well as the different levels of dependency in the team.
10. Adapt to multidisciplinary environments.
11. Communicate efficiently, orally and in writing, knowledge, results and skills, both professionally and to non-expert audiences.
12. Efficiently use ICT for the communication and transmission of ideas and results.
13. Respect diversity in ideas, people and situations.
14. Develop curiosity and creativity.
15. Use communication and computer applications (office automation, databases, advanced calculation, project management, display, etc.) to support the development and exploitation of telecommunication and electronic networks, services and applications.
16. Evaluate the advantages and disadvantages of different conceptual and technological options for different telecommunication applications.
17. Construct, operate and manage networks, services, processes and telecom applications, understood these as systems of recruitment, transportation, representation, processing, storage, management and presentation of multimedia information, from the point of view of the transmission systems.
18. Apply the techniques in networks, services, processes and telecom applications in both fixed and mobile environments, personal, local or long distance with different band widths, including telephony, radio, television and data are based from the point of view transmission systems.
19. Manage networks, services, processes and telecom applications according to the laws and regulations both domestically and internationally.
20. Distinguish the different nature of the problems of dimensioning and routing for each of the different types of networks and make decisions and initiatives to improve the operation and provision of telecommunications networks.
21. Carry out management activities for the design and dimensioning of telecommunications networks considering classical and new generation methods.
22. Differentiate and understand the significance of measurements and assessments of telecommunications networks to Formenta and ensure their optimal design.
23. Differentiate and classify the main algorithms dimensioning, traffic control and congestion.
24. Discuss and apply cryptography systems aimed at improving the safety of a telecommunication network.

Contents

PART I

I.1 Telecommunication Network Review

- Architecture of telecommunication networks: layer model, network edge, access and backbone networks
- Packet & Circuit Switching
- Basic IP Concepts: Packets, Routing, Packet Sizes, ARP, DHCP
- Evolution of the Internet infrastructure and architecture

I.2. Local Area Networks (LAN)

- Ethernet (IEEE 802.3): Physical layer, evolution, switching, frame format, collision & broadcast domains
- Loop Protection: Spanning Tree Protocol (STP, IEEE 802.1d), Rapid STP (RSTP, 802.1w)
- Link Aggregation: LAG/LACP (IEEE 802.3ad)
- Virtual Networks: VLANs (IEEE 802.1q), CoS (802.1p), QinQ (802.1ad)
- MLAG and Related Protocols (MC-LAG, vPC, etc.)
- VXLAN (RFC 7348): Overlay networks, encapsulation format, use cases in data centers
- Data Center Networking Architectures: Spine-leaf, Clos fabric, oversubscription

I.2b. Wireless LANs (Wi-Fi)

- Wi-Fi Overview: IEEE 802.11 family, frequency bands (2.4 GHz, 5 GHz, 6 GHz)
- Modulation and Physical Layer: OFDM, QAM, MIMO
- Wi-Fi Network Topologies: BSS, ESS, Roaming.
- MAC Layer Behavior: CSMA/CA, RTS/CTS, collision avoidance.
- Wi-Fi Standards Evolution: 802.11a/b/g/n/ac/ax (Wi-Fi 6/6E)
- Performance Characteristics: Bandwidth, latency, coverage, interference.
- Security and Management: WPA/WPA2/WPA3, authentication.
- Use Cases and Design Considerations: Dense deployments, enterprise, mesh Wi-Fi.

I.3. Access and Transport Networks

- Architecture of access networks and role in the Internet
- DSL (Digital Subscriber Line): ADSL, VDSL, signal modulation (DMT/OFDM), vectoring, crosstalk, PPPoE
- HFC (Hybrid Fiber-Coaxial): DOCSIS evolution, shared bandwidth model, coaxial properties
- PON (PassiveOptical Network): GPON, XG/XGS-PON, splitters, upstream/downstreamoperation, T-CONTs, ONU registration process. Optical transmission, wavelength bands, single-mode vs multi-mode fiber

I.4. Interconnection of Networks on the Internet

- Principles of network interconnection: Stub, transit, multi-homed
- Autonomous Systems (AS), Internet resource management (IP, ASN, RIRs)
- Routing algorithms: Bellman-Ford, Dijkstra
- Interior Gateway Protocols (IGPs): OSPF, IS-IS, RIP
- Exterior Gateway Protocol: BGP (eBGP/iBGP), route attributes, AS path, peering & policies

I.5. Internet Capacity and Service Quality

- Key metrics: Bandwidth, delay, jitter, packet loss
- Network capacity and overprovisioning
- Buffers: Size estimation (BDP), statistical multiplexing, bufferbloat
- Quality of Service (QoS): Queuing strategies (PQ, WFQ, LLQ), mouse vs elephant flows
- Integrated Services (IntServ) and Differentiated Services (DiffServ) models

I.6. Transport Protocols

- UDP: Lightweight, unreliable delivery
- TCP: Reliable delivery, flow control (sliding window), congestion control (Reno, Cubic, BBR)

- TCP Congestion Control Algorithms: Slow Start, Fast Recovery, BBR probing model
- QUIC / HTTP/3: Multiplexed connections over UDP, encryption and congestion control

I.7. Networking "Truths"

- RFC 1925: Fundamental truths of networking

PART II

II.1. Modeling systems using queuing theory

- General concepts: traffic, servers, queues, and service discipline
- Traffic characterization: exponential distribution, Poisson processes and Markov chains (discrete and continuous)
- Basic parameters and Kendall notation: number of servers, queue size, queue discipline, inter-arrival rate and time, service rate and time, response and waiting time, average server and queue occupancy, deadlock/wait/loss probability
- Little's law: performance, utilization and stability conditions

II.2. Dimensioning of telecommunication networks

- Introduction and requirements of network dimensioning: grade of service
- Sizing of a packet switching node: M/M/1 and M/M/m models
- Dimensioning of a fixed telephone network: M/M/c/c model (Erlang B, losses)
- Dimensioning of a cellular network: M/M/c/inf model (Erlang C, delays)

LABORATORIES

- Session 1: Local Area Networks (Ethernet: VLAN + LAG)
- Session 2: Internet Network Interconnection I (OSPF)
- Session 3: Internet Network Interconnection II (BGP)
- Session 4: Access and transport networks (GPON + VXLAN)

Learning activities and methodology

Title	Hours	ECTS	Learning outcomes
Resolució de problemes	12	0.48	1, 2, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24
Individual work of the student: practices preparation	18	0.72	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24
Individual work of the student: study and exercices resolution	70	2.8	1, 2, 3, 4, 5, 6, 7, 11, 12, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24
Pràctiques de laboratori	12	0.48	1, 2, 3, 4, 5, 11, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24
Theory lectures	26	1.04	1, 2, 3, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24

Tutories	2	0.08	1, 2, 3, 4, 5, 6, 7, 10, 11, 13, 14

Directed activities:

- Theory classes: delivery of theoretical contents
- Practical classes: solving questions and problems related to theory classes
- Laboratory classes: development of a challenge related to a course topic using hardware or simulators

Autonomous activities:

- Individual study of the subject: preparation of block diagrams, summaries and answering to questionnaires
- Problem solving: complement to the individual study and work prior to the practical classes

Supervised activities:

- Individual or group tutoring: aimed at resolving questions, advising on the development of the course, or attending to other specific issues

Annotation: within the schedule set by the centre or degree programme, 15 minutes of one class will be reserved for students to evaluate their lecturers and their courses or modules through questionnaires.

Assessment

Continuous assessment activities

Title	Weight	Hours	ECTS	Learning outcomes
Exams	70%	6	0.24	1, 2, 3, 4, 5, 6, 11, 17, 18, 19, 20, 22, 23, 24
Laboratory	30%	4	0.16	1, 2, 3, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24

1. Exams

Two assessment tests will be held during the course:

- Midterm exam (EX_QUEUES): fully assesses the Queueing Theory part.
- Final exam (EX_AP): fully assesses the Advanced Protocols part.

Resit. The resit exam allows students to improve, independently, the grade of each of the two theory parts. The queueing part grade will be the maximum between the midterm and the queueing exam of the resit (QUEUES_GRADE); likewise, the protocols part grade will be the maximum between the final exam and the protocols exam of the resit (AP_GRADE). In no case can the resit lower an already obtained grade. To be eligible for the resit exam, the student must have been previously assessed in activities representing at least two thirds of the course grade.

2. Lab work

Several lab activities will be carried out (the number may vary between 3 and 5 depending on the academic year) and a lab exam. Both the lab reports and the lab exam are non-recoverable activities. The grade for this part is computed as the average of the mean grade of the lab reports (MEAN_REP_LAB) and the lab exam grade (EX_LAB):

$$LAB\_GRADE = 0.5 \cdot MEAN\_REP\_LAB + 0.5 \cdot EX\_LAB$$

Lab reports that are not submitted are graded zero (0).

3. Final course grade

The final grade weights theory and lab work using the part grades (after the resit has been applied):

FG = 0.45 · AP_GRADE + 0.25 · QUEUES_GRADE + 0.30 · LAB_GRADE

The course is passed with an FG equal to or greater than 5.

Minimum grade. A grade equal to or greater than 3.5 must be obtained in each of the two theory parts (QUEUES_GRADE and AP_GRADE) separately. If this minimum is not reached in either part, the final course grade will be:

FG' = min(FG, 5)

Rounding of the final grade follows the UAB academic regulations.

4. Course rules

Late submissions. Late submissions are only accepted if requested in advance and accompanied by a valid justification (medical, work-related, etc.). For unjustified late submissions, a penalty of 1 point on the activity grade will be applied per day of delay, down to a minimum of zero (0).

Copying and plagiarism. Any irregularity -copying, allowing copying, or plagiarism- in an assessment activity results in a grade of zero (0) in that activity, regardless of any disciplinary process the University may open in accordance with its regulations. In the case of non-recoverable activities (lab reports and lab exam), this zero cannot be recovered.

Use of generative AI. In lab reports, teaching staff may convene ad-hoc oral tests if they detect the use of artificial intelligence as a substitute for personal effort and the development of competences.

Not Assessable. A grade of "Not Assessable" will be recorded when the student does not provide enough assessment evidence to allow an overall grade for the course. Specifically, a student will be considered Not Assessable if they have not taken assessment activities representing, in total, more than 20% of the final grade. Once this participation threshold is exceeded, the student will receive a numerical grade.

No carry-over between academic years. No assessment activity may be carried over or validated from one academic year to another. If a student enrols in a later year, they must complete and pass again all the assessment activities of the course: lab reports, lab exam, midterm exam, and final exam regardless of the grades obtained in previous years. Grades for parts, lab work, or tests are not retained or transferred from one year to the next.

Bibliography

PART I

- A. Tanenbaum, D. Wetherall. Computer Networks. Prentice Hall. 2011.
- W. Stallings. Data and Computers Communications. Pearson Education. 2014.
- Peterson & Davie. Computer Networks: A Systems Approach. Prentice Hall. 2014.
- Kurose & Ross: Computer Networking: A Top-Down Approach. Prentice Hall. 2014.

PART II

- Bertsekas, Dimitri, and Robert Gallager. Data networks. Athena Scientific. 2021.
- M. Harchol-Balter. Performance Modeling and Design of Computer Systems: Queueing Theory in Action. Cambridge University Press. 2013.
- J. F. Shortle, J.M. Thompson, D. Gross and C. M. Harris. Fundamentals of Queueing Theory. Wiley. 2018.

Software

Different software compatible with Windows, Linux and Macintosh will be used in the laboratories (i.e., Wireshark).

Course groups and languages

The information provided is provisional until November 30. After this date, you will be able to consult the language of each group through this link. To access the information, you will need to enter the course CODE

Type of teaching	Group	Language	Semester	Shift
(TE) Theory	330	English	second semester	morning-mixed
(PAUL) Classroom practices	331	English	second semester	morning-mixed
(PLAB) Practical laboratories	331	English	second semester	morning-mixed
(PAUL) Classroom practices	332	English	second semester	morning-mixed
(PLAB) Practical laboratories	332	English	second semester	morning-mixed
(PLAB) Practical laboratories	333	English	second semester	morning-mixed