ETSN10 Network Architecture and Performance
Course Outline 2019

1 Objectives

At the end of this course, you should be able to:

- Evalaute networking systems and identify their performance goals and constraints.
- Explain the operation of some well-known network protocols and related algorithms.
- Choose appropriate protocols and algorithms for a given network scenario.
- Create and analyse models of networks for the purpose of performance analysis.
- Analyse network performance using theoretical tools covered in the course such as stochastic processes and queueing theory.
- Analyse and evaluate experimental data.
- Describe current research problems and directions in networking.
- Find and critically evaluate information in the scientific literature.

The focus of this course is on wireless networks, but some topics from fixed networks will also be covered.

2 Teaching team

- Course co-ordinator and lecturer

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- Tutor

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3 Course website

The official course website is located at `http://www.eit.lth.se/course/etsn10`. We will also be using Moodle for this course. You can access Moodle by going to `http://elearning.eit.lth.se`, and logging in with your LUCAT username and password. Once you have logged in, you can enroll yourself in the course.

4 Assessment

The assessment for the course will consist of a 2.5cp project and an exam worth 5cp.

4.1 Project

The project consists of an introductory quiz, course readings, a system design task, and a system evaluation task. See the project description for more information.

4.2 Exam

The exam will contain a short-answer section and a section with longer problems to solve. The questions for the short-answer section will be drawn from the self-study questions available on the course website. The long-answer section will consist of some problems similar to those in the tutorials, including at least one system design problem that requires you to design a solution and justify your design, and at least one previously unseen problem. For examples of how the exam will be structured and the types of questions to expect, see the previous exam papers available on the course website.

5 Lectures

Module	Lecture	Textbook
0 (Online)	Networking review	Chapter 6, 8
1	Introduction, probability review, performance	Chapter 1, 2, 3, 5
2	Queueing systems	Chapter 4, 10
3	Medium access control	Chapter 9
4	Network architectures	Chapter 9
5	Network architectures, Modelling	Chapter 1, 5, 9
6	Congestion control	Chapter 8

6 Literature

6.1 Textbook

Performance Analysis of Computer Networks
Matthew N.O. Sadiku, Sarhan M. Musa
Springer 2013
ISBN: 978-3-319-01645-0 (Print) 978-3-319-01646-7 (Online)

The textbook is available for purchase from KFS or online at `http://link.springer.com/book/10.1007\%2F978-3-319-01646-7`.

6.2 Required readings

As part of the project, there are four required readings. In the weeks specified in the table below, you should read the text and answer the questions in Moodle. Your responses are due the Monday following the week the reading is assigned.

Week	Reading
1	Probability videos
2	Manshaei and Hubaux 2007
3	Yi et al 2015
4	Shafi et al 2017

6.3 Reference literature

The following books are not required for the course, but are recommended if you would like to read further on the course topics, or refresh your background knowledge.

- Mobile Communications
  Jochen Schiller, Addisson Wesley,
  ISBN 0-321-12381-6

- High Speed Networks and Internets: Performance and Quality of Service
  William Stallings, Prentice Hall
  ISBN 0-130-32221-0

- Queueing Systems Volume 1: Theory
  Leonard Kleinrock, Wiley Interscience
  ISBN 978-0-471-49110-1

7 Modules

Each module in the course consists of lectures and tutorials. Modules are of different sizes: some modules may be just one lecture and some questions in a tutorial session, while other modules contain multiple lectures and tutorials. Module 7.0 is online only and provides a review of assumed knowledge about basic networking concepts.

7.0 Online module: Networknig review

In this module we will cover:

- The TCP/IP networking stack
- Physical layer: types of medium (wired vs. wireless)
- Medium access control layer: Ethernet
- Network layer: IP
- Transport layer: TCP and UDP
- Routing algorithms: Dijkstra, Bellman-Ford
- Types of network: PAN, LAN, WAN

At the end of this module you should be able to:

- Explain the role of each of the layers in the TCP/IP stack
- Explain the operation of the following protocols:
  - IP
  - TCP
  - UDP
- Describe circuit switching and packet switching.
- Explain the steps of Dijkstra's algorithm and the Bellman-Ford algorithm and calculate the results of these algorithms for specific scenarios
- Explain the structure of an IP address
- Explain the functinos of transport layer protocols
- Explain encapsulation
- Relate application requirements to protocols at each layer of the TCP/IP stack, and determine characteristics needed for protocols at each layer to meet these requirements

7.1 Probability review

In this module we will cover:

- Basic probability axioms and theorems
- Conditional probability
- Random variables and distributions, in particular
  - Bernoulli
  - Binomial
  - Geometric
  - Poisson
  - Exponential
  - Gaussian (normal)
- Correlation and covariance
- Stochastic processes, in particular the Poisson process
- Statistical data analysis
- Confidence intervals

At the end of this module you should be able to:

- To pass the course:
  - Solve basic problems involving probability, including conditional probability
  - Calculate basic statistics of a data set, including the mean, and variance
  - Calculate confidence intervals
  - Give real-world examples of where each of the probability distributions covered arise
  - Solve problems involving the Poisson process, e.g. calculating the number of arrivals in a given time interval
- For a 4 or 5:
  - Model systems using probability theory
  - Solve more complex problems involving probability, e.g. multiple-stage conditional probability problems
  - Explain the three viewpoints of a Poisson process and how they relate to one another

7.2 Queueing systems

In this module we will cover:

- Little's Law
- Examples of queueing systems and their performance metrics
  - Single server Markovian (M/M/1)
  - Multiple servers with infinite buffer (M/M/2, M/M/∞)
  - Single server Markovian with finite buffer (M/M/1/N)
  - Markovian with multiple servers and zero buffer (M/M/N/N)
- Queueing networks and Jackson's theorem
- Queueing disciplines: priority queueing, fair queueing
- Self-similar traffic

At the end of this module you should be able to:

- To pass the course:
  - Select, from those covered in the module, an appropriate queueing system to model a given, familiar scenario
  - Apply supplied formulas to calculate performance metrics of queueing systems (average queue length, waiting time, etc)
  - Calculate the packet ordering for the queueing disciplines covered in specific scenarios
- For a 4 or 5:
  - Choose an appropriate queueing discipline for a given system and present arguments for your choice
  - Explain what is meant by self-similar traffic and its implications for queueing-theory analysis of network performance

7.3 Medium access control

In this module we will cover:

- Reservation schemes for medium access control in wireless networks
  - Space division multiple access
  - Time division multiple access
  - Frequency division multiple access
  - Code division multiple access
  - Demand assigned multiple access (explicit reservation)
  - Orthogonal frequency division multiplexing
  - Polling
- Random access schemes for medium access control in wireless networks
  - ALOHA (pure and slotted)
  - CSMA (non-persistent, p-persistent and 1-persistent)
  - 802.11 DCF
  - QoS for 802.11: EDCA, HCF
  - LoRa MAC
- Collisions, hidden and exposed nodes
- Energy efficiency in medium access control

At the end of this module you should be able to:

- To pass the course:
  - Explain the operation of each of the medium access control mechanisms covered
  - Calculate the signals at each stage of CDMA (encoding, multiplexing, demultiplexing and decoding)
  - Explain how OFDM can be used in medium access control
  - Apply supplied formulas to calculate performance metrics for the medium access control mechanisms covered
  - Explain collisions in wireless networks and mechanisms for handling them (acknowledgement and retransmittion, carrier sensing, backoff schemes such as exponential backoff)
  - Explain the hidden and exposed node problems and the operation of MACA (RTS/CTS) in 802.11

  - Explain how different medium access control mechanisms affect energy efficiency

- For a 4 or 5:
  - Choose appropriate medium access control mechanisms for a given system and present arguments for your choice
  - Compare and contrast the different medium access control mechanisms covered and give their advantages and disadvantages
  - Model and analyse the performance of previously unseen medium access control mechnaisms

7.4 Network architectures

In this module we will cover:

- Fixed vs wireless network topology
- Licensed vs unlicensed spectrum and its implications for wireless network architecture
- Architectures for unlicensed spectrum: infrastructure and ad-hoc
- Routing for wireless mesh networks
- Software defined networking
- The Internet of Things
- Cellular network architectures
  - GSM
  - UMTS
  - LTE
  - 5G

  At the end of this module you should be able to:

- To pass the course:
  - Explain the differences between licenced and unlicensed spectrum and between fixed and wireless networks, and the implications of these differences for network architecture
  - Describe each of the network architectures covered and their performance goals
  - Explain the operation of the routing algorithms coverd and calculate the results of these algorithm in specific scenarios
  - Explain the architecture and operation of GSM, UMTS, LTE, and 5G
- For a 4 or 5:
  - Compare and contrast the network architectures covered
  - Choose an appropriate network architecture for a given scenario and present arguments for your choice

7.5 Modelling

In this module we will cover:

- Reasons for creating models
- Types of models
- Analysis of models in terms of purpose, assumptions, and methodology
- Evaluation and validation of models
- The Kleinrock and Tobagi model of CSMA

- Bianchi's model of the 802.11 DCF

At the end of this module you should be able to:

- To pass the course:
  - Critically analyse a given model and describe its purpose, assumptions, and methodology
  - Explain how a given model could be (or was) evaluated and validated
  - Describe and analyse the Kleinrock and Tobagi model of CSMA
  - Describe and analyse Bianchi's model of the 802.11 DCF
- For a 4 or 5:
  - Create a model of a given system for a given purpose, and choose appropriate assumptions, methodology and evaluation techniques for it

7.6 Congestion control

In this module we will cover:

- Random Early Detection
- Traffic shaping
- Sliding window flow control in TCP
- Retransmission strategies in TCP

At the end of this module you should be able to:

- To pass the course:
  - Explain the operation of the congestion control mechanisms covered
  - Apply supplied formulas to calculate performance metrics for flow and congestion control mechanisms
  - Calculate round-trip times for TCP using supplied formulas
- For a 4 or 5:
  - Explain the reasoning behind the designs of the algoirthms and mechanisms covered
  - Choose appropriate congestion control mechanisms for a given system and present arguments for your choice

8 Lab

There will be a laboratory session in the first week of the course. The lab will focus simulation and data analysis. There will also be some optional tasks for those who have experience with computer programming.