Course Memo, Spring 2024

SSY145 – Wireless Networks, 7.5 credits

Introduction

The course focuses on wireless communication networks including wireless Internet. The aim is for students to acquire insights into the current state-of-the-art and of what technology is likely to be used in future systems. Another aim is to gain understanding of the impact of commercial, political as well as regulatory factors on the design and operations of wireless networks.

Course Website

Canvas page: https://chalmers.instructure.com/courses/29107.

Course Staff

Tommy Svensson, *Electrical Engineering (6413),* examiner, tommy.svensson@chalmers.se
Charitha Madapatha, *Electrical Engineering (6433)*, TA and supervisor, charitha@chalmers.se
Baraa Khuder, *Centre for Language and Communication*, lecturer, khuder@chalmers.se

Course Representatives

Emma Monique Hallantie	MPCSN	emppahal@gmail.com
Susanne On Huang	MPIDE	susselelle@gmail.com
Jacopo Puccini	MPICT	jackpuccio9@gmail.com
Galo Sanchez Granja	MPEES	galos@student.chalmers.se
Jahanvi Bhadrashetty Dinesh	MPICT	jahanvi@student.chalmers.se

Guest Lecturers (alphabetical order)

Tommy Svensson	E2, Chalmers	tommy.svensson@chalmers.se
Stefan Parkvall	Ericsson	stefan.parkvall@ericsson.com
Mikael Coldrey	*Ericsson*	*mikael.coldrey@ericsson.com*
Joakim Johansson	*Beyond Gravity (just retired)*	*jfj@telia.com*
Per Hjalmar Lehne	*Telenor*	*per-hjalmar.lehne@telenor.com*
Tomas Olovsson	*CSE, Chalmers*	*tomas.olovsson@chalmers.se*
Federico Tonini	*E2, Chalmers*	*tonini@chalmers.se*
Hui Chen	*E2, Chalmers*	*henkw@chalmers.se*
Lee Swindlehurst	*University of California, Irvine*	*swindle@uci.edu*

Lectures

A significant number of lectures will be given by experts from academia and industry focusing on the evolution of wireless networks both from technical and commercial viewpoint.
Most lectures will be in room ES51 (a few in ES53), Linsen, EDIT building.
There are big values in interacting with the lecturer and your classmates on campus, so default is that all students attend the lectures at campus in person.
However, in exceptional cases, for students that cannot attend a given lecture on campus, we will provide an online participation possibility via Zoom.
Then you can follow remotely in case you are sick or for other exceptional reasons cannot join on campus.
Zoom: https://chalmers.zoom.us/j/66661043586
Passcode for first Lecture: 406360.
Passcode for following lectures: the Passcode will be provided for exceptional cases upon motivated request by email to TA Charitha Madapatha charitha@chalmers.se, at least an hour before the lecture.
All lectures will be recorded and posted on Canvas (no password) to assist your learning by being able to go back to the lecture.

Group Project

The mandatory project is worth 60% of the final course grade. All groups should have one mandatory 1.5-hour consultation session (two groups at the time) with Baraa Khuder from the Centre for Language and Communication. The time of the sessions will be decided with Baraa Khuder early in the course.

Evaluation

The final grade consists of three parts:

a) Group project – 60% (min 30%)
   a. Planning report – 5%
   b. Progress report – 5%
   c. Final report – 30%
   d. Presentation – 15%
   e. Logbook – 5%
b) Quizzes – 15% (min 7,5%)
c) Final exam – 25% (min 10%)

Grade 3: ≥ 45% and < 65%
Grade 4: ≥ 65% and < 80%
Grade 5: ≥ 80%

Deadlines

Wed March 20 at 13:00	Submission deadline for *Project topic priority list* by each student.
Wed March 27	Submission deadline for the *Planning report.*
Fri April 19	Submission deadline for the *Progress report.*
Wed May 15	Submission deadline for the *Final report and review question(s).*
Mon May 20	Oral presentations (20 minutes plus up to 10 minutes for questions).
Mon May 20	Submission deadline for the *Presentation slides*.
Mon May 20	Submission deadline for the *Logbook*.
Tue May 28	Final exam at 08:30-12:30.

All above submissions should be uploaded to the course Canvas page. In particular, the Project topic priority list should be submitted to: "Quizzes>>Surveys>>Submit your priority list".

Supplementary Reading

- Ö. Bulakçı, M. Gramaglia, A. Gavras, M. Uusitalo, P. Rugeland, M. Boldi, “Towards Sustainable and Trustworthy 6G: Challenges, Enablers, and Architectural Design", Now Publishers, June 2023, Online here.
- Erik Dahlman, Stefan Parkvall, Johan Sköld, “5G/5G-Advanced The New Generation Wireless Access Technology”, Elsevier 3rd ed., 2023, Paperback ISBN: 978-0-443-13173-8, eBook ISBN: 9780443131745. Online here.
- M. Fallgren, M. Dillinger, T. Mahmoodi, T. Svensson, “Cellular V2X for Connected Automated Driving”, Wiley 2021. ISBN: 978-1-119-69264-5. Online here.
- Erik Dahlman, Stefan Parkvall, Johan Sköld, “5G NR: The Next Generation Wireless Access Technology”, Academic Press, 2018, ISBN: 9780128143230.
- Erik Dahlman, Stefan Parkvall, Johan Sköld, “4G: LTE/LTE-Advanced for Mobile Broadband,” Academic Press, 2011, ISBN: 978-0-12-385489-6.
  Can be accessed at: http://www.sciencedirect.com/science/book/9780123854896[1].
- Andrea Goldsmith, “Wireless Communications,” Cambridge University Press, 2005, ISBN-13: 9780521837163.
- Stefania Sesia, Issam Toufik, Matthew Baker, “LTE, The UMTS Long Term Evolution: From Theory to Practice”, John Wiley and Sons, 2009.
- Theodore S. Rappaport, “Wireless Communications: Principles and Practice (2nd Edition),” Prentice Hall PTR, 2002, ISBN 0130422320.

[1] In case this direct link does not work: Go to www.sciencedirect.com, choose ”BIBSAM Chalmers University of Technology, Library” and then search on 4G LTE/LTE-Advanced for Mobile Broadband as journal/book title.

- Dave Wisely, "IP for 4G," Wiley, 2009, ISBN 9780470510162
- William Stallings, "Data and Computer Communications (8th Edition)," Prentice Hall, 2006, ISBN-10: 0132433109.

The Different Steps in the Project:

1. **Choosing a topic:** Each student should choose four preferred topics, with priority 1 (highest), 2, 3, and 4 (lowest). The priority list should be submitted in **Canvas "Quizzes>>Surveys>>Submit your priority list"** before the deadline. The groups (of three students) will be assigned as fair as possible based on their priorities.
2. **Planning report:** Each group should present what main objectives the group has set up for the project, what delimitations and scope that have been established. Furthermore, the document should also give account for the planning of the project, including a time chart for different tasks to be completed. ***Requirements*:** 2-3 pages based on the below mentioned guidelines. The report should be uploaded on the course Canvas page before the deadline. ***Guidelines*:** The document should at least contain the following. (i) *Title*: A preliminary informative title should be stated. (ii) *Background/Introduction*: The background should introduce to the topic and motivate why the topic is interesting to study from a research[2] point of view. (iii) *Main Objective*: The aim of this part is to identify the research question that will be treated in the project. It should also state the likely outcome of the project. (iv) *Scope*: The scope should specify the parts of the research question that will be covered and which parts that will not be covered. (v) *Time chart*: A detailed time plan indicating various tasks of the project.
3. **Progress report:** Each group should describe the progress of the project. Findings, ideas, and problems with the progress of the project should be part of the document as well as an outline of the final report and a list of references. ***Requirements*:** 2-5 pages based on the below mentioned guidelines. The report should be uploaded on the course Canvas page before the deadline. ***Guidelines*:** The document should at least contain the following. (i) *Title*: A reasonable title that is specific to the research question under study (ii) *Background/Introduction*: A more matured introduction to the topic based on the literature survey done so far. (iii) *Progress*: The aim is to describe the accomplished tasks, acknowledged problems (technical or non-technical), and planned activities (iv) *Findings*: It should state the proposed solutions/methods to the research problem based on the literature (v) Outline of the final report with brief description of each section including proper references.
4. **Final report:** The report should be in IEEE format and should give readers a clear picture of the scope, objectives as well as the results/findings of the project. Target readers are your classmates. Together with the report, each group should also define at least one review question that brings up a central issue of the project (will be used as a basis for the exam). The final reports will be made available on the course Canvas page to be read by all students attending the course. ***Requirements*:** The report should be written in IEEE format using word or latex (maximum of 5 double column pages). The report and review question(s) *with motivated answer* should be uploaded on the course Canvas page as two separate documents before the deadline. ***Guidelines*:** The quality of the final report should be similar to that of an IEEE conference publication.
5. **Presentation:** All group members should present the finalized project at a mini conference. The presentation should be using PowerPoint-slides (or equivalent). Note that all the materials used in the presentation should be prepared by the group. This means that it is not possible to use any previously published pictures, illustrations, or simulation results. ***Requirements*:** PowerPoint slides (or equivalent) for 20 minutes plus questions. The slides should be uploaded on the course Canvas page before the deadline.
6. **Logbook:** The logbook should include a description of how the group has worked with the project, what meetings have been held and what decisions have been taken. What has been

[2] Note that with the word 'research' we here mean to make an in-depth, targeted study of a hot topic, i.e. not to create new knowledge in that field of research.

done by each individual should be clearly stated. ***Requirements*:** The report should be uploaded on the course Canvas page before the deadline.

Proposed Project Topics

1. **Access procedures in cellular networks** (random access, scheduling, power control, mm-wave initial access, NOMA, ...)
2. **Cooperative communications in cellular networks** (Relaying, Coordinated Multi-point Transmission (CoMP), Cell-free Massive MIMO)
3. **Heterogeneous Networks** (HetNet, femtocell, Integrated Access and Backhaul, (IAB))
4. **Converged communication, localization, and sensing** (cooperative localization and sensing using wireless networks, location-aided communications, integrated sensing and communication (ISAC)/ joint communication and sensing (JSAC))
5. **WiFi** (the IEEE 802.11 family, WiFi 6E).
6. **Multi-antenna techniques in wireless networks** (massive MIMO, mm-wave, (sub-)THz, Reconfigurable intelligent surfaces)
7. **Machine-to-machine communications** (M2M, MMC, IoT, LoRa, Sigfox, RFID, IoT applications, ...)
8. **Energy efficiency and sustainability in wireless networks** (Green Communication, Sustainable 6G design, 6G for sustainability)
9. **Cognitive radio** (including Intelligent radios)
10. **Satellite and high altitude platforms for communications** (GEO, LEO, UAV, Starlink, …)
11. **Optical wireless communications** (LiFi, Free Space Optics, Visible Light Communication)
12. **5G New radio** (NR waveform design, hardware constraints, standardization, …)
13. **Architecture and network slicing in 5G and Beyond** (in the core network, machine learning based, Data-driven intelligence, …)
14. **Backhauling and fronthauling** (fiber, microwave, mm-wave, THz, distributed MIMO)
15. **Wireless communications in Industry automation** (Industry 4.0, 5G private networks, Zigbee, Digital twinning…)
16. **Vehicular communications** (V2X, Cellular-V2X, ITS-G5, …)
17. **Security in wireless communications** (protocols, physical layer security, …)

Quizzes

Many lectures will start with a 10 min quiz that can be found in **Canvas "Assignments>>Quiz>>Ax"** (all lectures marked with a **blue Ax** (Answer quiz number *x*) in the schedule on the next page) with four multiple-choice answers (a maximum of four points). One week before these lectures an article(s) that is connected to the lecture (or lectures if the quiz is on a Monday) is made available on the course Canvas page. The questions in the quiz can be from the article(s), or from the previous lecture (or the two previous lectures on Monday if the quiz is on a Thursday). Solutions to Quiz "Ax" can be found in **Canvas** "Modules>>Quiz solutions>>Ax_solutions"

The students also receive one point if they submit one “reasonable” quiz question with four multiple-choice answers from each of the lectures marked with a **green Cx** (Create quiz question *x*) in the schedule on the next page. *The correct answer should also briefly be motivated.* The quiz question should be submitted in **Canvas "Assignments>>Quiz question submission>>Cx ...”.** It is **mandatory** for the students to use the **latex template** provided on the course Canvas page for creating their quiz question. The question together with the four multiple-choice answers (with motivation) should be uploaded to the course Canvas page **within 24 hours** after the lecture.

All questions used as the basis for the quiz (from the articles and from the lectures provided by the lecturer or submitted by the students) without answer will be posted on the course Canvas page before the quiz (as soon as they become available).

There is a maximum of 15 points from submitted questions and a maximum of 4 points on each of the 13 quizzes. In total the quizzes can therefore give 67 points, which is equivalent to 15% of the final grade. A minimum of 33 points on the quizzes (7,5% of the final grade) is therefore required to pass the course.

Exam

The exam consists of questions from the articles, the lectures (provided by the students and the lecturer), and the final reports (provided by the students).

Schedule, Answer quiz (Ax), Create quiz question (Cx)

Please note the times in red!

Italics guest lectures are to be confirmed.

Ax	Room ES51/ES53*	Speaker	Content	Cx
1	Mon Mar 18 13:15-15:00	Tommy Svensson E2, Chalmers	**Introduction, course organization, overview of wireless networks**	
2 A1	Thu Mar 21 10:00-11:45	Baraa Khuder Language, Chalmers	**Academic Technical Writing**	C1
3 A2	Mon Mar 25 13:15-15:00	Tommy Svensson E2, Chalmers	**Basic Principles of Wireless Networks**	C2
	Mon Mar 25 15:15-16:00	*Work on Technical scope of your project.* Consultation available.	*Work on Technical scope of your project. Consultation available.*	
Re-exam week and Easter break				
4 A3	Mon Apr 8 15:15-17	Tommy Svensson E2, Chalmers	**Multi-carrier Communications**	C3
5 A4	Thu Apr 11 10:00-11:45	*Mikael Coldrey* *Ericsson*	***Wireless Backhaul – Introduction and Evolution***	C4
6 A5	Mon Apr 15 13:15-16:00	Stefan Parkvall Ericsson	**5G and Beyond – Part 1**	C5
7 A6	Thu Apr 18 09:00-11:45	Stefan Parkvall Ericsson	**5G and Beyond – Part 2**	C6
8 A7	Mon Apr 22 13:15-16:00	Tommy Svensson E2, Chalmers	**mmWave and sub-THz Communications in 5G and Beyond**	C7
9 A8	Thu Apr 25 09:00-11:45	Tommy Svensson E2, Chalmers	**Cellular-V2X and Outlook Towards 6G**	C8
10 A9	Mon Apr 29 13:15-15:00	*Federico Tonini* *E2, Chalmers*	***Network Slicing***	C9
11	Mon Apr 29 15:15-17:00	*Joakim Johansson* *Beyond Gravity (retired)*	***Space Communications***	C9’
12 A10	Thu May 2 10:00-11:45	*Tomas Olovsson* *CSE, Chalmers*	***Wireless Security***	C10
13 A11	Mon May 6 13:15-15:00	*Per Hjalmar Lehne* *Telenor*	***Spectrum Management Concepts for Mobile and Wireless Communications***	C11
14	Mon May 6 15:15-17:00	*Henk Wymeersch, E2* *E2, Chalmers*	***5G/6G Radio Localization Basics***	C11’
15	Mon May 13 13:15-17:00	*Håkan Lönnqvist, Jan Palmqvist* *Ericsson*	***Visit Ericsson, Lindholmen***	
16 A12	Thu May 16 10:00-11:45	Baraa Khuder Language, Chalmers	**Presentation Skills**	C12
17	Mon May 20 **12:45-17:45**	Students	**Mini conference – Presentations of projects**	
18 A13	Thu May 23* 08:00-09:45	*Lee Swindlehurst, UCI*	***Energy Efficient Massive MIMO Communications***	C13
19	Tue May 28 08:30-12:30	Students	**Exam**	

*Note: Quiz questions from **C9, C9’** will both be part of **A10**, quiz questions from **C11, C11’** will be part of **A12**. Quiz submissions from **C13,** are counted towards the Quiz score, but will not appear in the Exam.*