



Teaching Modelling and Analysis of Communication Networks using OMNeT++ Simulator

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- 1. Teaching Concepts**
- 2. Exercises: OMNeT++ and INET**
- 3. Challenges**
- 4. Conclusion**

- ▶ **Project based learning course**
 - More on methods of scientific and engineering work than on learning information by heart
 - Learn in an interactive manner than just as pure listeners
 - Smaller groups, encouraging discussions with peers

- ▶ **Teach the theoretical background of simulations with hands on experience**
 - One simulation tool
 - Students actively work to reflect theoretical understanding
 - Specific tasks in teams

Simulation and Modelling of Communication Networks (SimMCN)

- ▶ **Theoretical Knowledge:**
 - Concepts of discrete event simulation
 - Modelling of communication network

- ▶ **Capabilities:**
 - Present the results and discuss solutions
 - Explained the effects observed
 - Question their own results

- ▶ **Social Competence:**
 - Acquire expert knowledge in groups
 - Work out solutions for new problems in small teams

- ▶ **Autonomy:**
 - Work self-reliantly

- ▶ **Single semester (14-week) for Masters level**

- ▶ **4-hour per week**
 - 90 minutes Lecture
 - 150 minutes Group Exercises
 - Discussions, presentations and working with the simulator

- ▶ **6 ECTS**

- ▶ **Work load**
 - 70 hours of study time during the semester
 - 110 hours of independent study time

- ▶ **Oral examination with a final task**

- ▶ Lecture 1 - Simulation Basics
- ▶ Lecture 2 - Stochastics
- ▶ Lecture 3 - Random Number Generation
- ▶ Lecture 4 - Statistical Analysis of Simulation Results
- ▶ Lecture 5 - Simulation Models
- ▶ Lecture 6 - Hypothesis Testing
- ▶ Lecture 7 - Wireless Networks
- ▶ Lecture 8 - Advanced Topics in Simulations

Outcome 1 – Theoretical Knowledge

Organisation of Exercises and Final Examination

▶ 8 Exercises

- Basic understanding of OMNeT++ (3 weeks)
- Analysis and validation of results (3 weeks)
- Modelling and performance evaluation of communication networks (2 weeks)

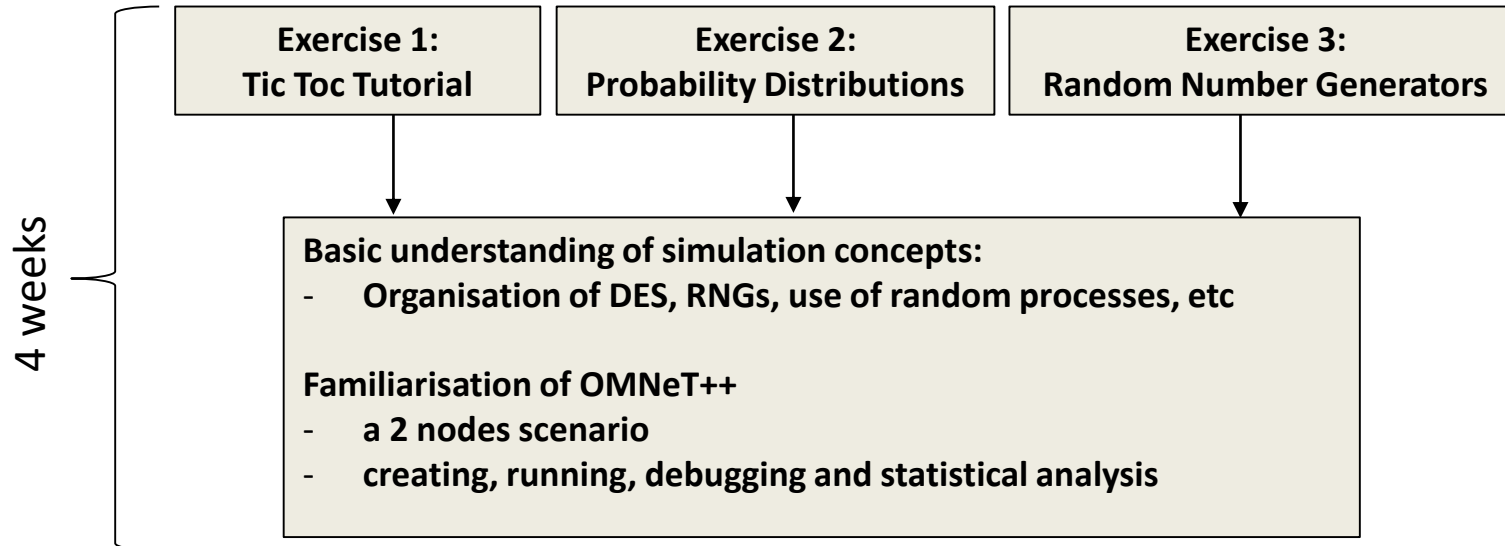
▶ Final examination

- Final task to complete with 2 students
At the end of the semester, 4 more weeks
- Submission of a report and 20 minutes presentation

Outcomes

2 – Capabilities, 3 - Social Competence, 4 - Autonomy

Exercises: Understanding Simulation Concepts



Learning Targets of Exercise 1 – Tic Toc Tutorial:

- Setting up an OMNeT++ project
- Debugging and running

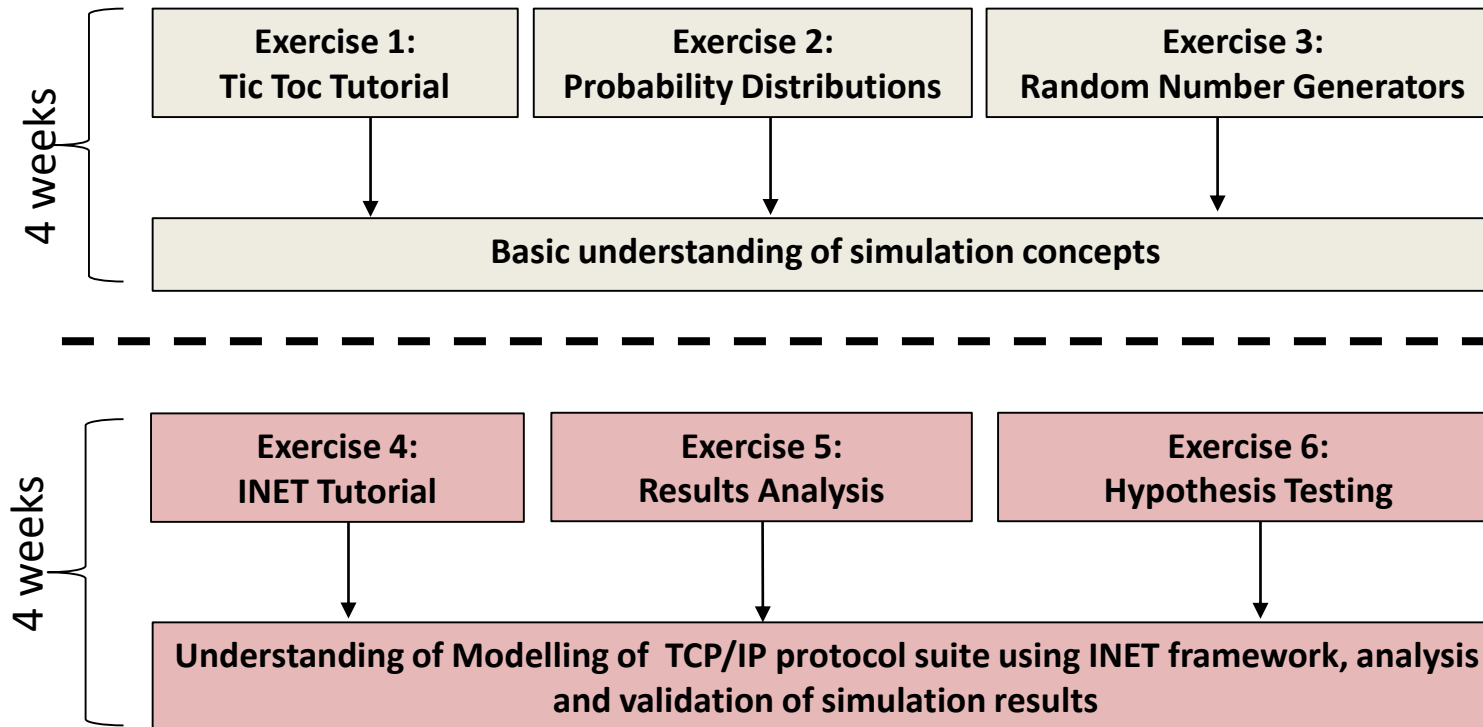
Learning Targets of Exercise 2 - Probability Distributions :

- Understand the lecture 2
- Stochastics by analysing the PDF and CDF of packet inter-arrival times
- Compare the results w.r.t. a lower and higher number of samples or simulation durations
- Compare the mean and variance of simulation results with theoretical computations

Learning Targets of Exercise 3 – Random Number Generators:

- Deeper understanding of the theory learned in lecture 3
- RNGs by implementing an own RNG (e.g., LCG generator)
- Investigate the effect on results of different RNGs (seed, period)
- Getting used to modifying C++ code.

Organisation of Exercises and Final Examination



Learning Targets of Exercise 4 – INET Tutorial:

- Understand the difference between vector and scalar files
- Analyse the TCP throughput observing how TCP congestion control algorithm works
- See the impact on the upper layer performance by changing the link parameters

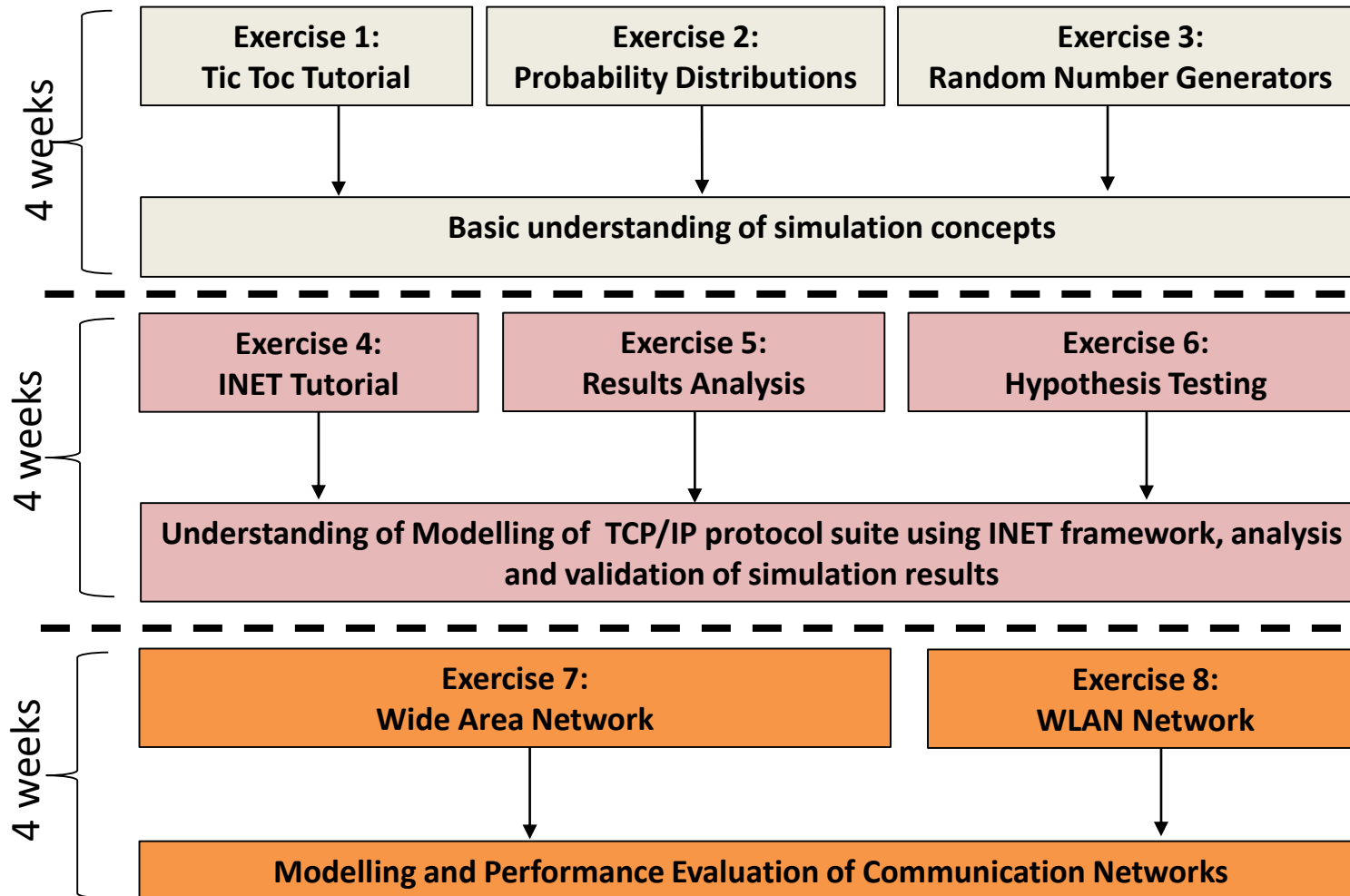
Learning Targets of Exercise 5 – Results Analysis:

- Deeper understanding of lecture 3 - Analysis of Results and lecture 5 - Simulation Models
- Visualise the effect of the warmup period due to the TCP slow start phase
- Observe the variation of the size of the confidence interval when increasing the number of runs and number of samples used in a single run

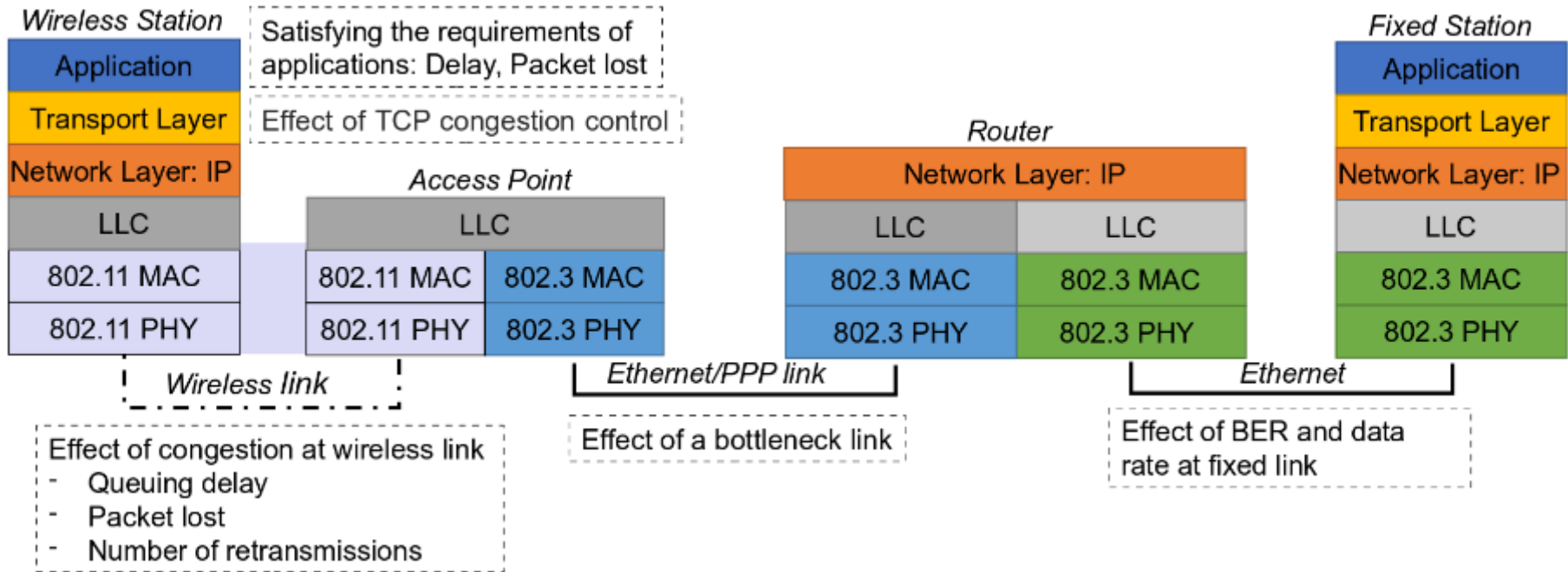
Learning Targets of Exercise 6 – Hypothesis Testing:

- Know how to use empirical data in a simulator
- Deeper understanding of the goodness of fit test learned at lecture 6 - Hypothesis Testing
- Use of MATLAB functions.

Organisation of Exercises and Final Examination



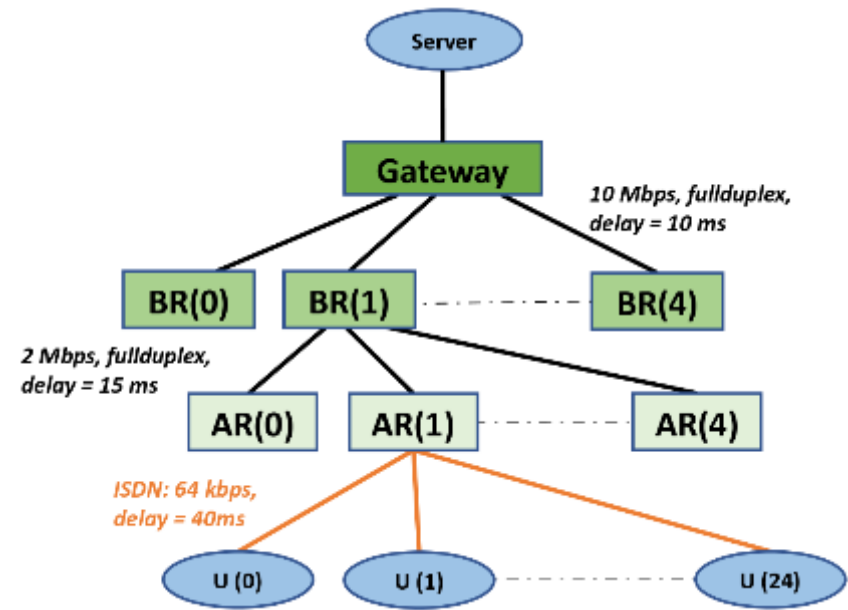
Exercises: Modelling and Evaluation of Communication Networks



Exercises: Modelling and Evaluation of Communication Networks

Learning Targets of Exercise 7 – WAN Task

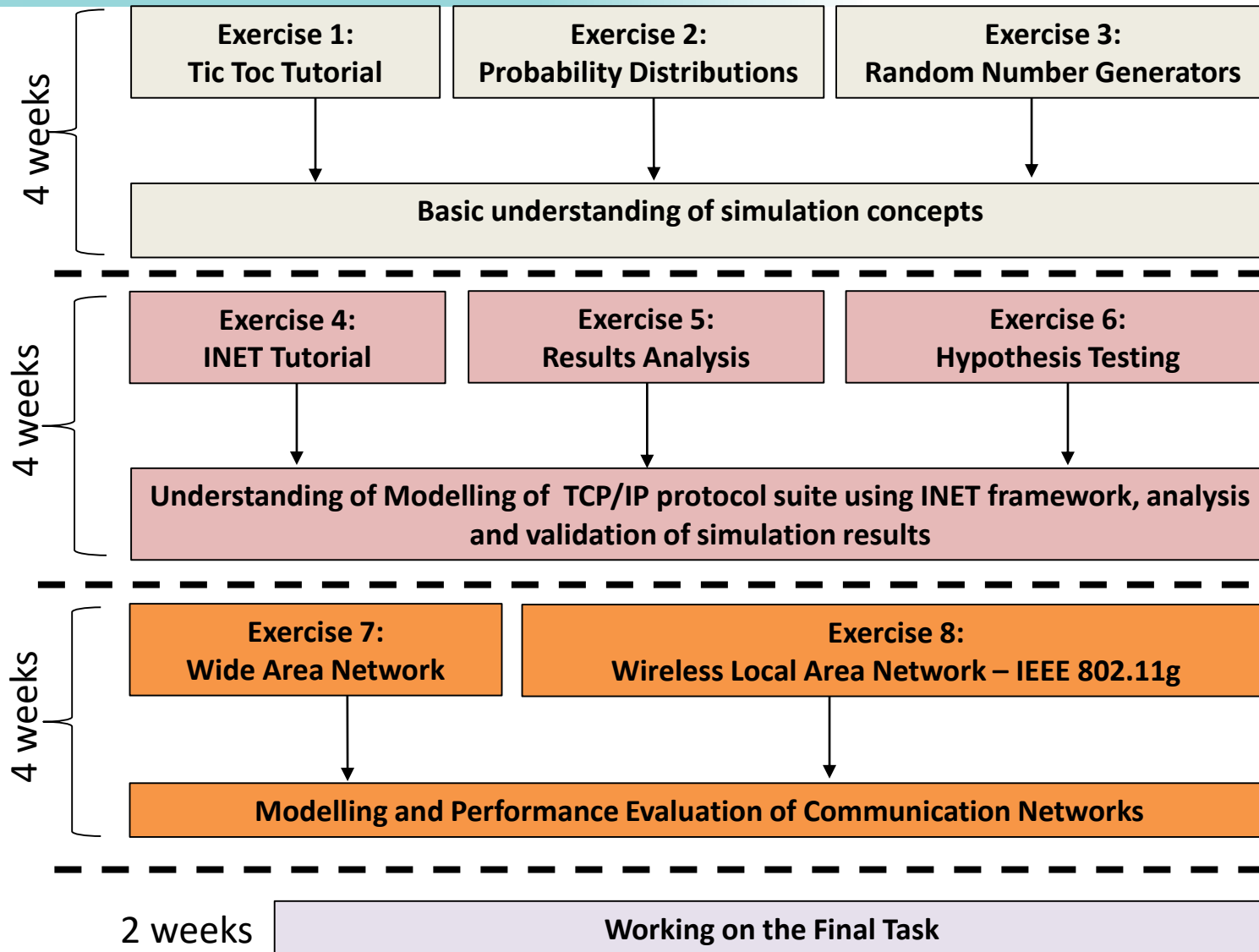
- Understand a text description
- Justify the simulation parameters used (e.g., simulation duration, warmup period, number of repetitions, etc)
- Add new statistics: packet loss due to large delay
- Modify application protocols
- Use the simulation models to analyse the worst case scenario
- Give a presentation justifying the results.



Learning Targets of Exercise 8 – WLAN:

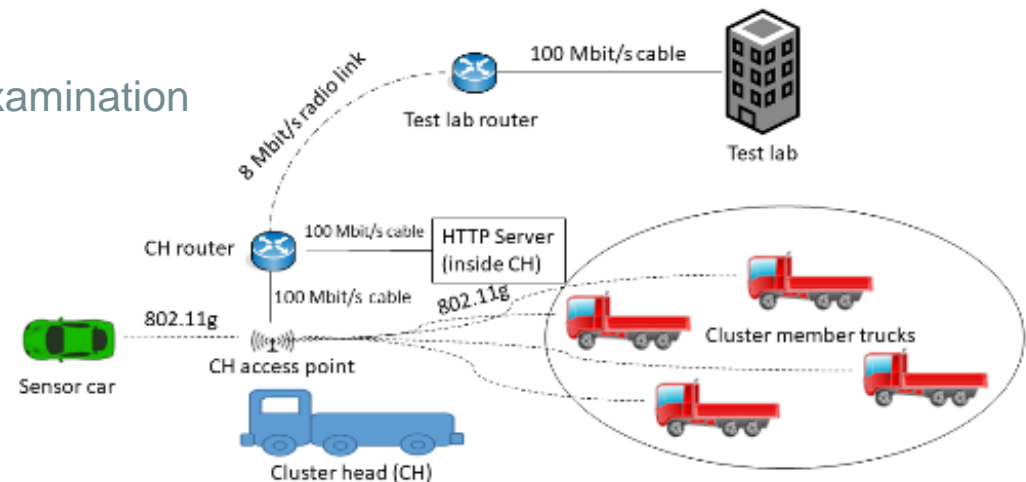
- Understand the behaviour CSMA/CA using a simple network
- Configuration of required parameters used in WLAN
- Analysis of results by investigating IEEE 802.11 based statistics
- Setting up the routing table.

Organisation of Exercises and Final Examination



Final Task - Overview

- Given 13th week of the study time
- 2 students in a group
- 2 weeks full time workload
- Report submission and oral examination



Final Task - Objectives

- Modelling of data given in a trace file
- 2 sub tasks: FTP upload and FTP download scenarios
 - How many cluster members can be supported?
 - Identifying bottlenecks, queuing delays, packet loss rates
 - They suggest network improvements
 - Analysis with confidence intervals and justification of simulation parameters

- ▶ **High resource utilisation**
 - All tutors should know OMNeT++ and INET
 - Many rooms required
- ▶ **Heterogeneous student backgrounds**
 - Local and international Master's programs
 - Lecture scripts
- ▶ **Lack of programming skills**
- ▶ **Students' work habits**
 - Just to pass / learning information by heart
 - Keep up students' motivation
 - Students' attendance and contribution for the exercises are also considered in grading

- ▶ **Project based learning course**
 - Teach the theory with hands on experience
 - More resources are required
 - Outcome of the course is not only teaching theory, but also enhance the practical & soft skills

- ▶ **Single semester (14-week) for Masters level**
 - 7 Lectures and 8 Exercises

- ▶ **Students feedback**
 - Hard to complete the final task without attending all the exercises
 - Comfortable to work with OMNeT++ or any other simulator when doing thesis work, after attending this course

- ▶ **All our materials are available online**
 - OMNeT++ 5.2.1 and INET 3.6.4



Thank you for your attention!

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