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

Koojana Kuladinithi, Raphael Elsner, Leo Krüger, Sebastian Lindner, Christoph Petersen, Daniel Plöger, Zeynep Vatandas, Andreas Timm-Giel

Institute of Communication Networks, Hamburg University of Technology
Contents

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

¬ 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)
SimMCN: Teaching Outcomes

- **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
SimMCN: Overview

‣ 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 Contents

- 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

- Exercise 1: Tic Toc Tutorial
- Exercise 2: Probability Distributions
- Exercise 3: Random Number Generators

Basic understanding of simulation concepts:
- Organisation of DES, RNGs, use of random processes, etc

Familiarisation of OMNeT++
- a 2 nodes scenario
- creating, running, debugging and statistical analysis

4 weeks
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

Exercise 1: Tic Toc Tutorial
Exercise 2: Probability Distributions
Exercise 3: Random Number Generators

Basic understanding of simulation concepts

Exercise 4: INET Tutorial
Exercise 5: Results Analysis
Exercise 6: Hypothesis Testing

Understanding of Modelling of TCP/IP protocol suite using INET framework, analysis and validation of simulation results
Exercises: Use of INET Framework

**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

Exercise 1: Tic Toc Tutorial
4 weeks

Exercise 2: Probability Distributions

Exercise 3: Random Number Generators

Basic understanding of simulation concepts

Exercise 4: INET Tutorial
4 weeks

Exercise 5: Results Analysis

Exercise 6: Hypothesis Testing

Understanding of Modelling of TCP/IP protocol suite using INET framework, analysis and validation of simulation results

Exercise 7: Wide Area Network
4 weeks

Exercise 8: WLAN Network

Modelling and Performance Evaluation of Communication Networks

4 weeks
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

- **Exercise 1:** Tic Toc Tutorial
- **Exercise 2:** Probability Distributions
- **Exercise 3:** Random Number Generators

4 weeks

- Basic understanding of simulation concepts

4 weeks

- **Exercise 4:** INET Tutorial
- **Exercise 5:** Results Analysis
- **Exercise 6:** Hypothesis Testing

4 weeks

- Understanding of Modelling of TCP/IP protocol suite using INET framework, analysis and validation of simulation results

4 weeks

- **Exercise 7:** Wide Area Network
- **Exercise 8:** Wireless Local Area Network – IEEE 802.11g

4 weeks

- Modelling and Performance Evaluation of Communication Networks

2 weeks

- Working on the Final Task
Final Task and 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
Challenges

- **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
Conclusion

- **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!

www.tuhh.de