Chair for Network Architectures and Services—Prof. Carle
Department of Computer Science
TU München

Discrete Event Simulation

IN2045

Dipl.-Inform. Alexander Klein
Dr. Nils Kammenhuber
Prof. Dr.-Ing Georg Carle

Chair for Network Architectures and Services
Department of Computer Science
Technische Universität München
`http://www.net.in.tum.de`

Teaching—I8 Overview

- Lectures

  SS:

  - Introduction to Computer Networking and Distributed Systems (IN0010)
  - Peer-to-Peer-Systems and Security (IN2194)
  - **Discrete Event Simulation (IN2045)**

  WS:

  - Master Course Computer Networks (IN2097)
  - Network Security (IN2101)

- Seminars
  - Seminar – Network Architectures and Services: Network Hacking (IN0013)
  - Advanced Seminar – Innovative Internet Technologies and Mobile Communications (IN8901)
  - Advanced Seminar – Future Internet (IN8901)
  - Advanced Seminar – Sensor Networks(IN0014), with Prof. Baumgarten
- Lab Courses
  - Bachelor Practical Course – Internet Lab (IN0012)
  - Master Practical Course – Computer Networks (IN2106)

Course organization IN2045 Discrete Event Simulation

- Lecture
  - Wednesday 14:15–15:45, FMI 03.07.023 (starting Wed 25 May 2010)
  - Block course, ca. 3 days between 20–24 September 2010
- Students are requested to subscribe using a Web form at www.net.in.tum.de ⇨ Lehre ⇨ Vorlesungen ⇨ …
  - http://www.net.in.tum.de/de/lehre/ss10/vorlesungen/
  - Will be used for sending up-to-date information (e.g., room changes)
  - Email list for subscribers of course
  - **Unrelated to subscription in TUMonline!**
- Questions and Answers / Office hours
  - Dipl.-Inform. Alexander Klein, klein@net.in.tum.de, 03.05.061
    Office hours: Mon 13–14
  - Dr. Nils Kammenhuber, kammenhuber@net.in.tum.de, 03.05.043
    Office hours: usually Thu, Fri 14–15, but check via e-mail first
  - Prof. Dr. Georg Carle, carle@net.in.tum.de
    Office hours: Upon appointment (typically Mon 16–17)
- Course Material
  - Slides are available online. Slides may be updated during the course.

Grading

- Course is 4 ECTS
  - 2 SWS lectures
  - 1 SWS exercises
- Exercises
  - Prepare for the oral examination
  - Successfully participating at exercises gives a bonus of 0.3 on the overall grade. [Exercises = same time slot as lecture.]
- Our concept for grading
  - Final examinations will be oral and give an individual grade.
  - You must pass the oral exam for being successful in the course (i.e., 4.3 and 0.3 bonus ≠ 4.0)
- Subscription in TUMonline
  - Warning: Subscription on www.net.in.tum.de does not replace subscription via TUMonline!
  - Deadline: ca. 20 Sep 2010

Questions

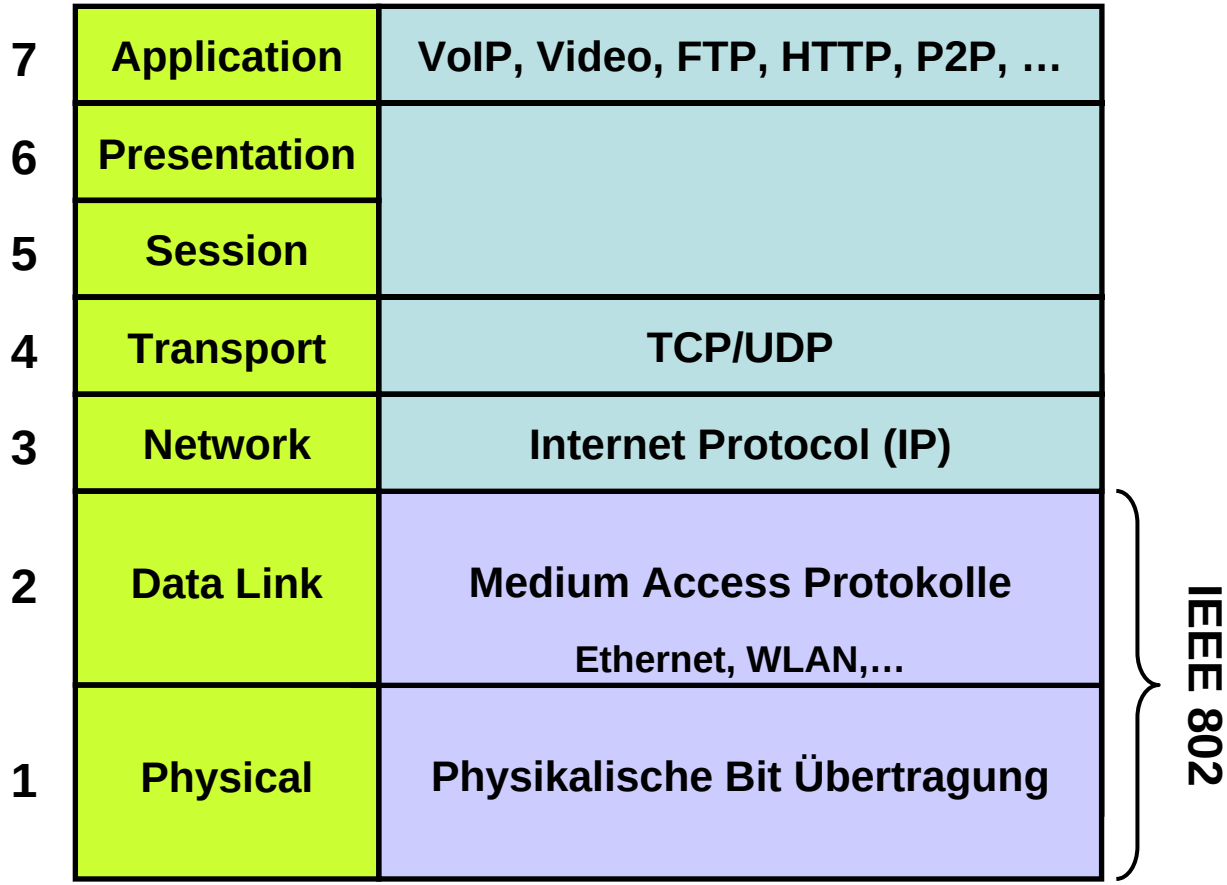
- Who studies what?
  - Diploma degree?
  - Master in Informatics?
  - Master in Information Systems [Wirtschaftsinformatik]?
  - Other Master courses?
  - Bachelor in Informatics?
  - Exchange students from other universities?
- Which previous relevant courses?
  - Rechnernetze/Computer networks?
  - Masterkurs Rechnernetze/Master course computer networks?
  - Grundlagen Betriebssysteme/Operating Systems?
  - Other courses, e.g., Simulation and Modelling?

Course outline (tentative)

1. Introduction
   - ❑ Motivation: When and why to do simulation
   - ❑ Types of simulation
   - ❑ Event-driven simulation
   - ❑ Process-oriented simulation
   - ❑ Typical Work Flow Elements
   - ❑ A simple queuing model; some queuing theory

Simulation vs. Analysis

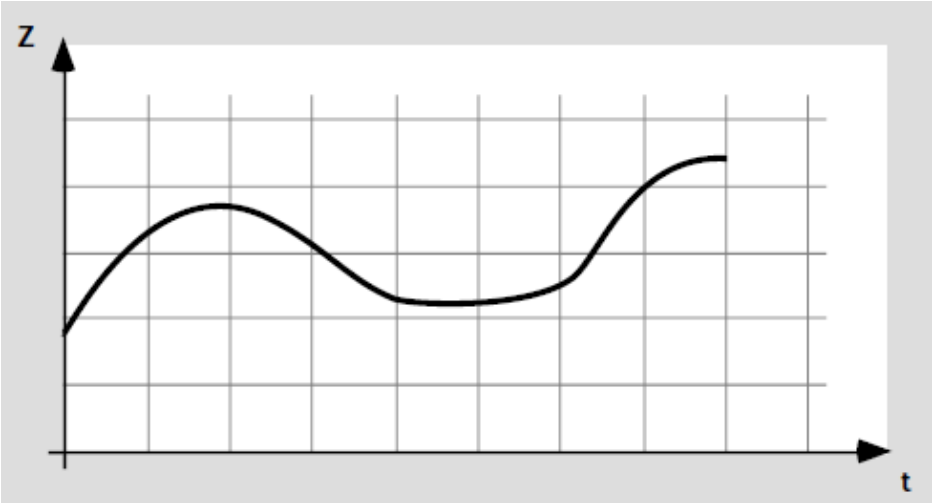
ISO / OSI



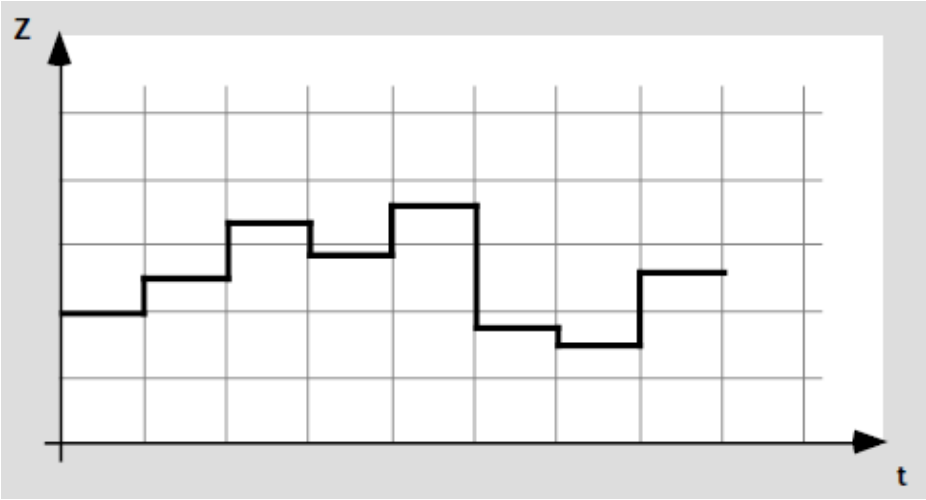
Course outline (tentative)

2. Statistics fundamentals
   - ❑ Contents shall be embedded into practical context
   - ❑ Basics and descriptive statistics (mean, variance, moments)
   - ❑ Discrete vs. continuous random variables
   - ❑ Visualization
   - ❑ Probability distributions and their properties

Statistics fundamentals



Continuous



Discrete

Course outline (tentative)

3. Random numbers
   - ❑ How to generate a desired probability distribution
   - ❑ [pseudo-] Random number generators
   - ❑ Evaluation of random number generators

Random number generator

Example:

00101111010100110110001001110101010001 1

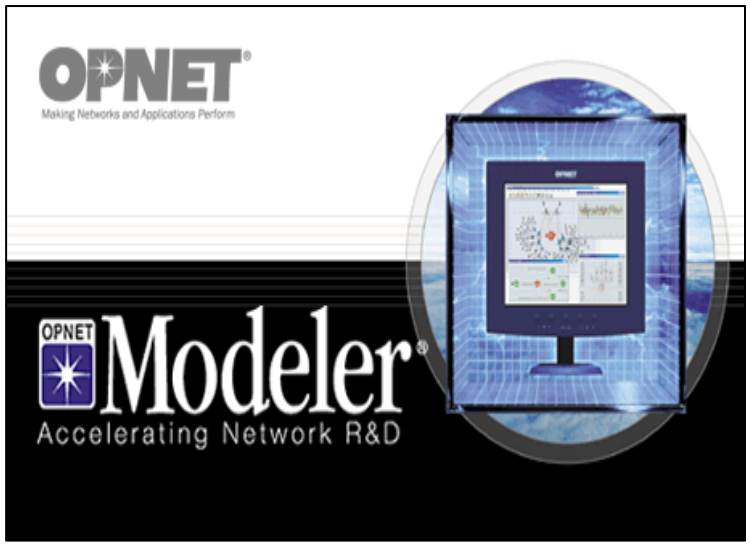
00101111010100110110001001110101010001 1

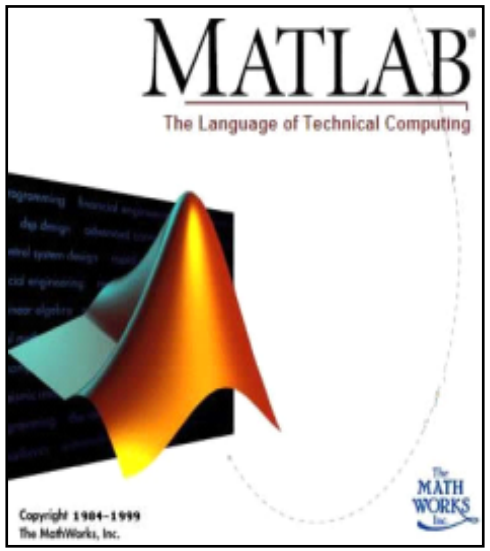
Random

Autocorrelation Lag 4

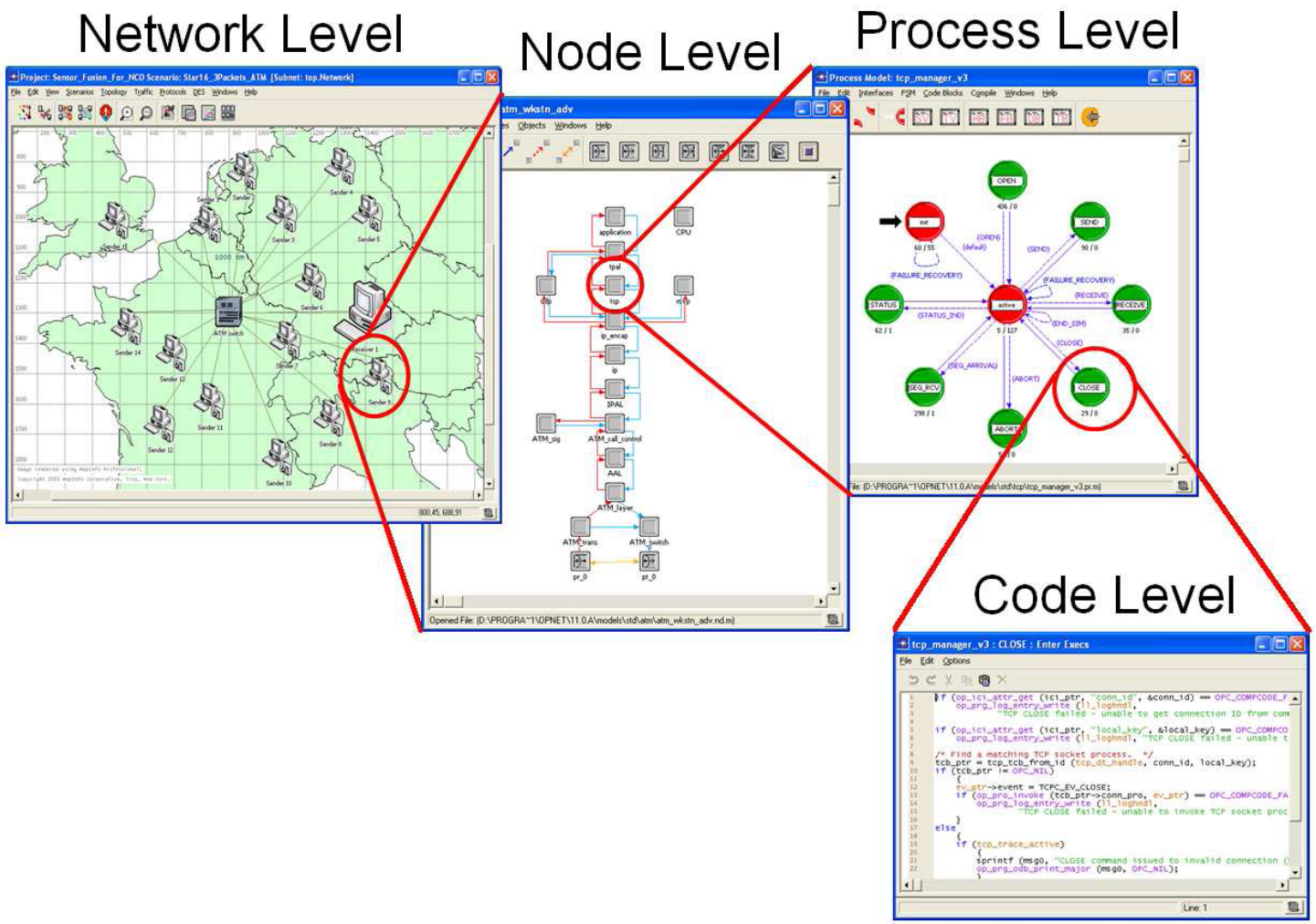
Course outline (tentative)

4. Tools
   - ❑ OPNet
   - ❑ Matlab

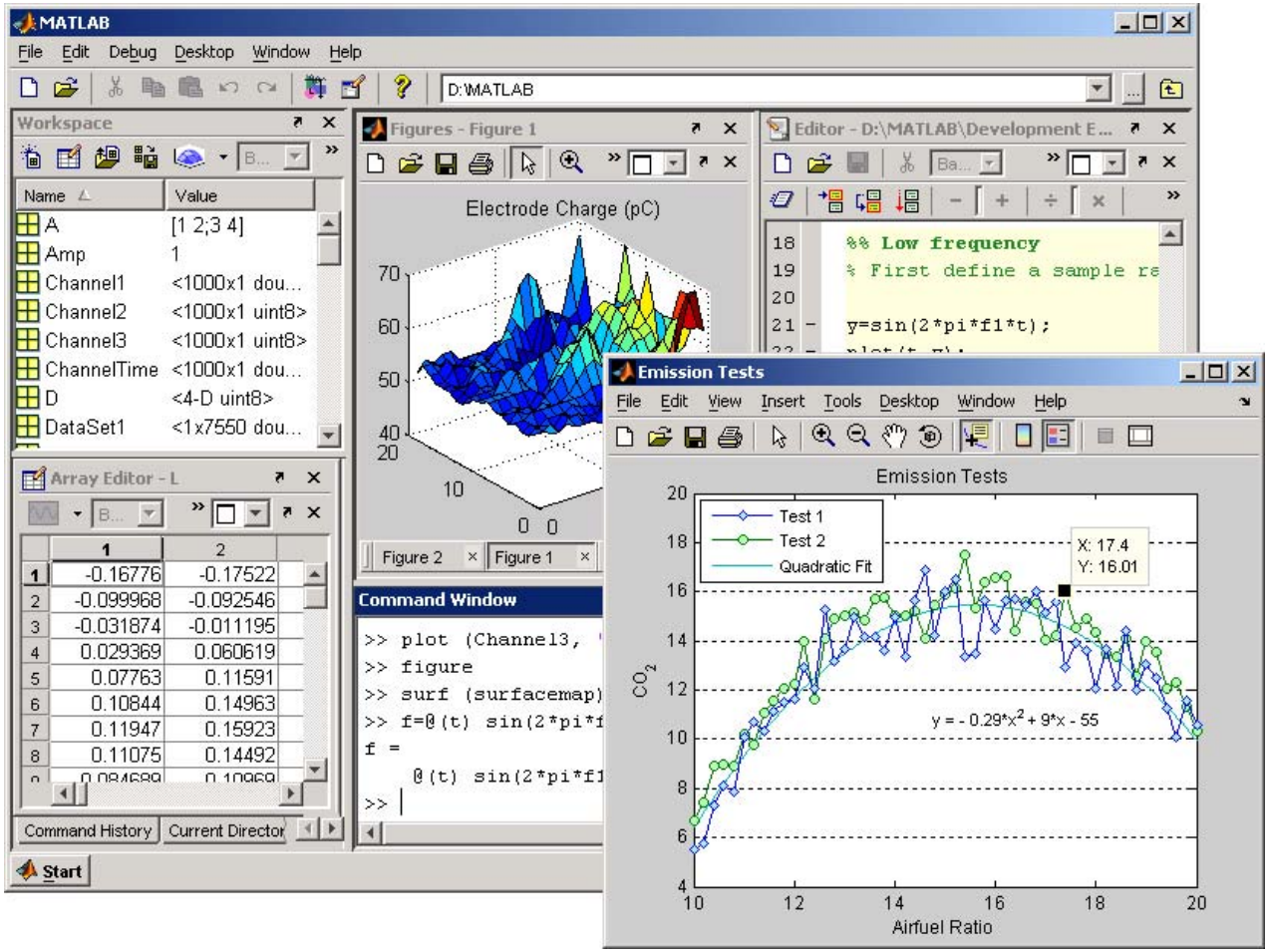




OPNET



Matlab



http://www.mathworks.de/

Course outline (tentative)

5. Experiment planning
   - ❑ Factorial design
   - ❑ Factor analysis, ANOVA

Factorial design

Problem:

- Large number of parameters
- No detailed knowledge of the impact of the parameters

Idea:

- Variation of simulation parameters (valid configurations)
- Evaluation of the system performance
- Identification of the impact of each parameter on the system performance

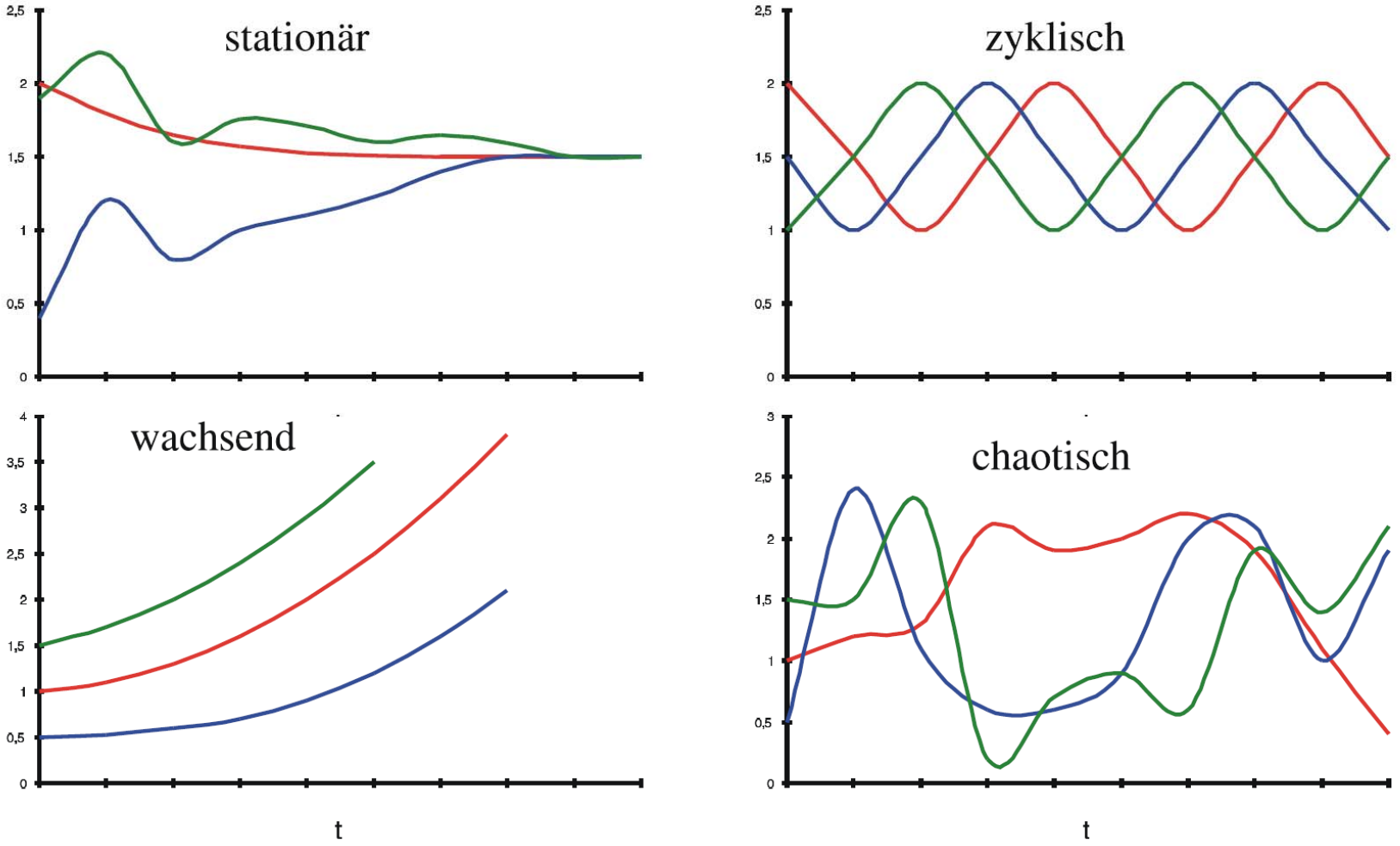
Simulation / Parameter	X1	X2	X3	X4	Result (X1,X2,X3,X4)
# 1	+	-	-	+	38
# 2	o	+	+	o	12
# 3	-	o	-	+	43
# 4	-	+	+	+	12
# 5	-	-	-	-	15
# 6	o	o	o	o	8

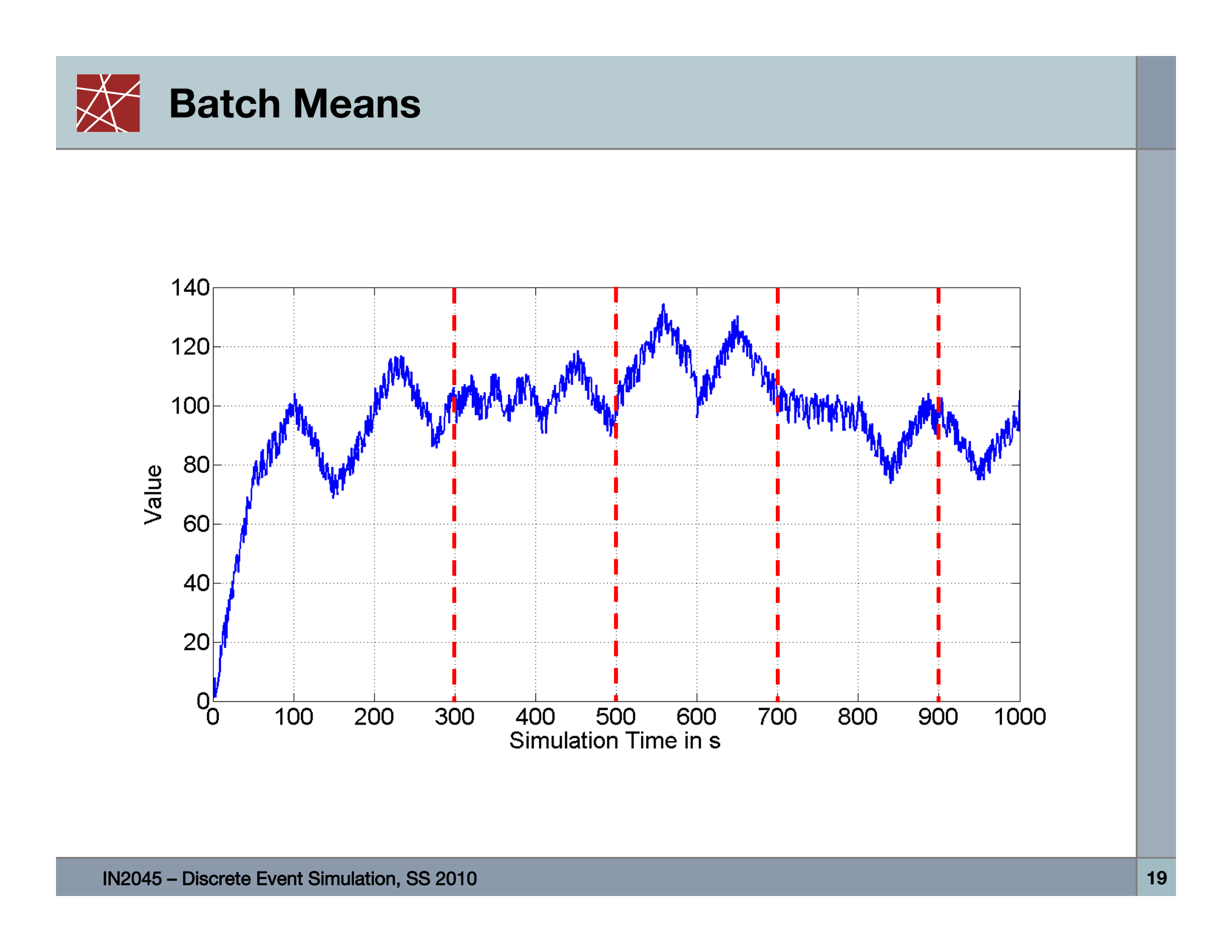
Result Table

Course outline (tentative)

6. Evaluation of simulation results: More statistics ☺
   - ❑ Variability reduction
   - ❑ Confidence intervals
   - ❑ Visualization
   - ❑ …

Stochastic processes: taxonomy





Batch Means

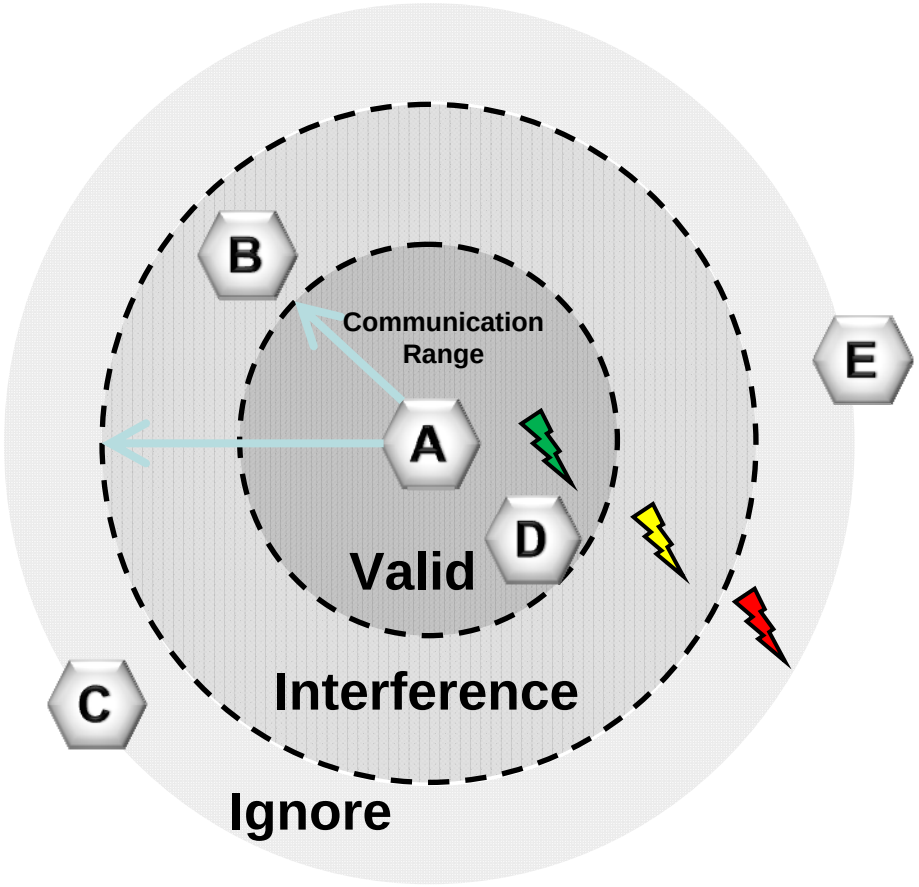
140
120
100
80
60
40
20
0
Value
0
100
200
300
400
500
600
700
800
900
1000
Simulation Time in s

Course outline (tentative)

8. Tips and tricks from practice
   - ❑ What constitutes a good network simulator
   - ❑ How to set up a good simulation
   - ❑ How to do a good analysis of simulation output
   - ❑ How to lie with statistics
   - ❑ How to speed up your simulation

Course outline (tentative)

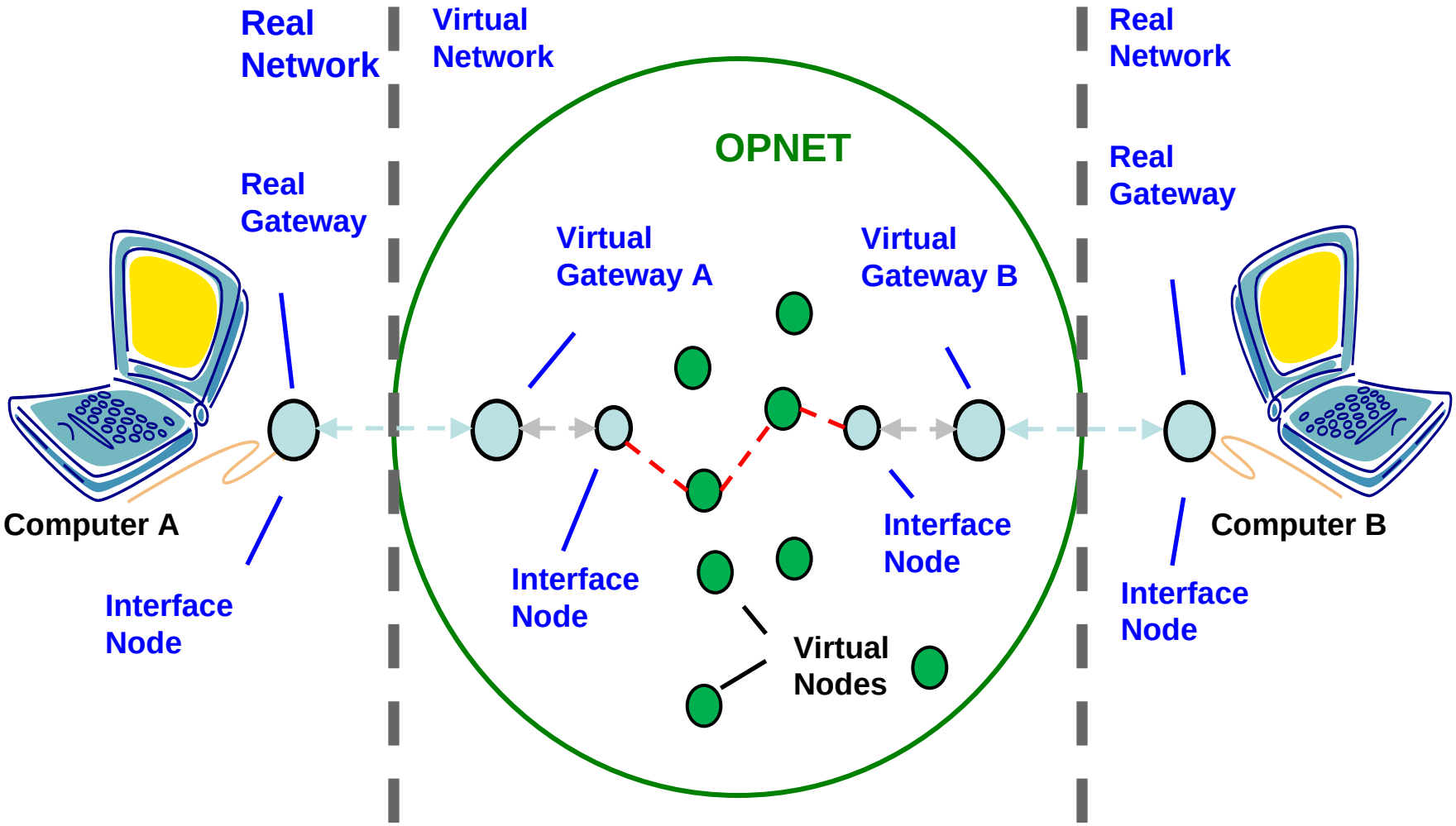
- Example:
  - Wireless Communication (Disc Model)



Course outline (tentative)

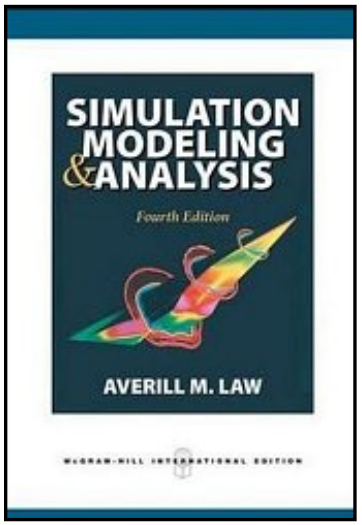
9. Advanced topics
   - ❑ Mobile networks, mobility models
   - ❑ Co-Simulation / Parallel simulation
   - ❑ Hardware-In-The-Loop Simulation

Hardware-In-The-Loop-Simulation



Material

- Book:
  Simulation Modeling and Analysis
  Averill M. Law
  4th edition
  McGraw-Hill, 2007



- Lecture notes:
  - Parallel and Distributed Simulation Systems
    Richard Fujimoto
    College of Computing, Georgia Institute of Technology
  - Modellgestützte Analyse und Optimierung
    Peter Buchholz, Informatik IV, TU Dortmund
  - Simulation of computer systems and computer networks:
    A process-oriented approach
    J. B. Sinclair, Rice University
  - Einführung in die Simulationstechnik
    Frank Wagner, Joachim Warschat, Universität Stuttgart