Modeling and Tools for Network Simulation

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In Favour of Network Simulation

A lot of research in computer science and electrical engineering is being carried out in the field of distributed systems and computer networks. Topics being addressed include the development of new and improved protocols, applications, architectures, security and quality-of-service techniques, just to name a few. A crucial step during the design and engineering of communication systems, respectively protocols, algorithms and architectures, is the estimation of their performance, and the understanding and visualization of the micro and macro behavior of the systems and their components. Typically, this can be (more or less) realized by applying three different methodologies: (1) experiments with real systems and prototypes, (2) mathematical analysis, and (3) simulation.

In research and development of communication systems the latter two methodologies are most important during the conceptual phase, since prototyping such systems is mostly infeasible due to financial and technical constraints. Simulation is particularly used for systems which are highly dynamic and whose properties are difficult to capture in a mathematical way. Often, analytical methods show the borderline behavior of system characteristics or offer upper and lower bounds for specific research questions. However, more fine grained analysis often leads to an unacceptable complexity of the analytical models. In contrast, simulation offers scientists and researchers a controlled environment in which a system can be investigated in more detail. Different parameter sets and scenarios can be analyzed with comparably little effort. Thus, simulation is a powerful and versatile methodology to analyze and visualize the behavior and performance of communication systems and networks.

Considering simulation as the methodology to analyze a communication system (which may not even exist), one has to consider a very important fact: All simulations are carried out on models of the system under investigation and not on the system itself. All models have to be created in advance. Since analyzing a system without prior modeling is not possible, and as all inferred knowledge is deducted from the model itself, the process of modeling is crucial for the overall process of simulation-based evaluation. Considering the importance of the modeling process for the quality of the observed results, it is very surprising and disappointing, which techniques are known and applied to guarantee high-quality simulation models. Typically, next to some very generic guidelines – like the following – there exist no further rules, methods, techniques or just a simple cookbook to create and assure adequate simulation models:

"*All actions, events and properties have to be modeled as accurately and with as much detail as possible.*" But on the other hand: "*... only as accurately and with as much detail as actually needed and required.*" Another important aspect of simulation-based evaluation is the comparison of approaches, such as protocols and algorithms. Up to now, this has rarely been possible in the

area of communication systems, since most models are highly specialized for the respective investigation. Often, models are made for a distinct context of investigation, and hence, they are neither compatible nor comparable to other competing models or approaches. This means that a reasonable comparison between research carried out by different parties is practically impossible.

In our opinion, these problems are fundamental facts about network simulations. While it appears as if an unified modeling methodology is missing, there is no such method that suites all considered systems in networking research. In contrast, especially over the last few years, the networking community has developed a set of "best-practice" approaches for different problems at different layers. In addition, a large set of tools have evolved that support the modeling, the programming and the execution of simulation code for the evaluation of networks at all layers. However, common text books do not address these topics, and furthermore, typical simulation courses only focus on the fundamentals of simulation, but not on best practice or on tools for network simulations. This was the motivation for this book.

This book is the result of a workshop to which PhD students from all over Germany were invited to present and discuss their experiences. The intended audience of this book are graduate students, PhD students, researchers, and professionals with interest in computer networks, wireless networks, and performance evaluation of networks by means of simulation. The book is organized in three parts. Part I contains material about tools and methods for network simulations. In this part two famous and widely used network simulators and two special simulators are described. Furthermore, the usage of parallel simulation, the simulation of hardware aspects considering the simulation of networks, and the integration of simulators with real systems are addressed. The focus of Part II is on models for simulation of the lower layers of the network protocol stack, particularly the lower layers of wireless networks. The topics covered span the modeling of the physical layer, link layers, communication channels, mobility, and handover. Part III contains models for the simulation of higher layers of the protocol stack. Most of the models discussed in this part can be used for wired networks as well as for wireless networks.

Finally, this book would not have been finalized without the help and support of many people. Primarily, we thank all authors for their valuable contributions. Furthermore, we are grateful for the support of:

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More information on the book and slides on selected topics of the book can be found on this website: `www.network-simulation.info`.

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Simulation is an inevitable methodology for specification, design and analysis of computer and communication networks. It is extensively used at all levels ranging from hardware to network. However, to obtain valid results that properly predict the behavior of a real system, all relevant effects must be captured in the simulation model. This task has become very challenging today, since one can rarely model and simulate the different levels in isolation. Rather, advanced system optimization causes dependencies in the behavior across all layers. Further, systems have become extremely complex and so have the simulation models. To get relevant statistical results and to cover critical corner cases the simulated time (i.e., the time elapsed in the simulated system) has to be sufficiently long. To avoid excessive simulation time even on high-performance computers, modeling not only has to be proper but also efficient.

Abstraction of lower layer effects in higher layer simulation models always has been a formidable task. Because of the increasing cross layer optimization, however, this task has become significantly more challenging. Finding the right way of combining the simulation models of different layers is a key issue. While plain co-simulation of layers yields the highest precision, it usually results in low simulation speed. Abstraction of effects in other layers and efficient modeling are a key to higher simulation speed but require a lot of care to capture all relevant behavior.

Therefore, it has become essential for engineers and computer scientists to understand the modeling and simulation concepts applied to different layers of a network. As this book addresses both modeling and simulation techniques at all levels, it is extremely useful and very timely. It should become a handbook for all engineers involved in computer and communication system simulation.

Finally, a short word of advice: To understand the behavior of a particular system it is not sufficient to perform a huge amount of simulations. Simulations must be set up to address the right questions and the results must be analyzed thoroughly and be interpreted properly. Simulation does not replace the use of the brain. But when used right, it is an extremely powerful tool.

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