Editorial

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"Modeling of Self-Organizing Systems"

In the last decade, we witnessed the unparalleled success of communication networks such as the Internet or wireless mobile communication networks.[1] The unprecedented scale of the aforementioned networks does not mark the end of the growth, but the emergence of wireless sensor networks and the "Internet of Things" are going to further add to the complexity of today's communication networks.

For providers and network operators to be able to plan, build, and maintain next generation networks, it is necessary to push the envelope of traditional means to control the network. From a user's perspective, the organic growth of autonomously operated (community) networks and of application-level overlay networks presents further challenges.

Self-organization is foreseen to play a major role in future communication networks. Obviously, this shift in paradigm from tightly controlled towards self-organizing networks leads to a variety of open research challenges. Solutions to these challenges are pivotal in either leveraging the possible advantages of self-organizing systems, but could also turn out to be a heavy burden for both operators/providers and users.

The goal is clear: after purposefully introducing (artificial) means of self-organization, the beneficial features – often identified as the so-called self-* properties – should clearly outnumber the critical ones. Thus, it is essential for the research community as well as for manufacturers/operators to learn how to design, engineer, optimize, and control complex, and often even chaotic systems in a structured and purposeful way. To select and parameterize different approaches, a systematic methodology for the comprehension and application of self-organizing behavior is needed. For development and application of such a methodology, the modeling and evaluation of system properties plays a key role.

This PIK special issue surveys the topic of self-organization with special emphasis on mathematical modeling techniques to describe self-organizing behavior. The call for papers was very well received and yielded a relatively high number of submissions. Each paper has been rigorously scrutinized by at least three independent experts. Detailed feedback to the authors and a re-assessment of the accepted submissions has further fostered the quality of this special issue.

The special issue has been structured into the following three topic areas:

(1) Terminology and conceptual models of autonomous systems.
(2) Analytical frameworks and mathematical models of self-organizing and complex systems.
(3) Tool support as well as application of models.

[1] As of November 2007, the number of hosts in the Internet is estimated to be ~500,000,000 (cf. http://www.isc.org); at the same time roughly 2,500,000,000 subscribers are using mobile phones (cf. http://www.gsm-world.com).

The first paper in this issue, "Autonomie in IT-Systemen – Ein Konzeptionelles Modell" (in German), by Jaeger, Werner, Mühl, Heiß, Laude and Ruge gives a concise definition of the topic area "autonomous computing" with particular emphasis on non-functional characteristics such as quality of service and dependability. A conceptual model is developed that relates the key aspects of autonomous systems: the system (including development process and methodology), its architecture-related aspects as well as the system's characteristics.

The paper on "Worst Case Modelling of Wireless Sensor Networks" by Schmitt and Gollan gives an overview of the state-of-the-art in worst-case modeling for wireless sensor networks. In particular the methodology of network calculus is investigated and the various extensions towards a unified framework that captures the behavior of WSNs are discussed. The work also highlights some challenges that persist and need further research, such as the probabilistic nature of the wireless channel. A comprehensive toolset of the discussed techniques has been made available by the authors at http://disco.informatik.uni-kl.de/content/Downloads.

The paper "Applying random walks in structured and self-organizing networks: Evaluation by transient analysis" of Hasslinger and Kempken presents a thorough analysis of random walks (as opposed to flooding approaches) in the context of peer-to-peer networks. Transient analysis is used as a simple and scalable approach to examine the properties of random walks in random as well as structured overlay topologies. Moreover, the convergence to steady state and the coverage of the network are studied analytically.

Kersch and Szabo present "A graph theoretical lower bound on maintenance overhead of structured P2P overlays". In particular, they analyze the maintenance overhead of dynamic peer-to-peer networks. They model both stable as well as transient states of the network (due to join and leave events) and analyze the graph-edit distance, which allows estimating the minimum communication overhead in maintaining the topology operational. The presented results aid in detecting bottlenecks of the topology-maintenance mechanism in P2P systems.

Wüchner, Sztrik, and De Meer study "The Impact of Retrials on the Performance of Self-Organizing Systems". The work is motivated by (but not limited to) the challenge to accurately model peer-to-peer systems such as eDonkey and eMule. A stochastic Petri net is proposed that includes the modeling of retrials – a feature that is essential to realistically capture the above networks, but has so far often been neglected in formal models. Using a comparative performance analysis, the authors demonstrate the predictive power of their model.

Reichle, Khan, and Geihs tackle the interesting research problem of structural (compositional) adaptation of self-organizing systems in their work "How to Combine Parameter and Compositional Adaptation in the Modeling of Self-Adaptive Applications". The authors introduce a combination of compositional adaptation with parameter adaptation at run-time, which is able to synergistically couple the benefits of both approaches.

Balázsfalvi and Sztrik propose "A tool for modeling distributed protocols". The work introduces an analytical model to describe peer-to-peer networks that is based on cellular automata. Thus, the work is opening up a new avenue of research by departing from today's predominant tool for P2P research, i.e., discrete-event simulation. Using simple abstractions as well as the real-world example of BitTorrent, the authors demonstrate the feasibility of their modeling approach.

The final paper in this issue, "Model-driven Performance Simulation of Self-organizing Systems with PartsSim" by Becker, Gotzhein, and Kuhn, investigates the trade-off between realism and accuracy in modeling wireless sensor networks. The authors build on a model-driven development process using SDL and enhance the base model with various extensions to capture the real world characteristics and bottlenecks of the sensor nodes. Using a simple application example, the authors are able to demonstrate the predictive power of the enhanced model.

Building on the principle of self-organization is considered to be decisive in the ability to build the communication systems of the future. Towards this end, this PIK special issue represents a collective effort towards structuring the research domain "Modeling of Self-organizing Systems". We would like to thank the authors, which contributed significantly to advance the state-of-the-art in this research area, and Christopher Auer and Dr. Karin Hummel for their kind support during the review process. As guest editors of this special issue we further wish to especially thank Prof. Mauve, co-editor in chief of the PIK journal, for his excellent advice and support in this effort; we also wish to thank Dr. Ritter and Dr. Kruse, co-editors in chief, for their work behind the scenes.