Universität Basel

Publication

Artificial physical chemistry: Analysis and design of communication and networking systems

Thesis (Dissertationen, Habilitationen)

ID 2992974
Author Monti, Massimo
Author at UniBasel Monti, Massimo ;
Year 2014
Title Artificial physical chemistry: Analysis and design of communication and networking systems
Type of Thesis Dissertation;
Start of thesis 01.08.2010
End of thesis 17.09.2014
Name of University Universität Basel
Name of Faculty Philosophisch-Naturwissenschaftliche Fakultät;
Supervisor(s) / Fachvertreter/in Tschudin, Christian ;
Keywords Artificial Chemistry, Emergent Control, Consensus, Convergence and Sensitivity Analysis, Algorithm Dynamics, Hardware Implementation
ă

In this thesis, we use concepts, principles, and theoretical results from Physical Chemistry to engineer communication and networking systems. We focus on system dynamics and exploit laws from chemical kinetics in order to govern the dynamics of a communication network. This is achieved by orchestrating the interactions among network nodes by means of “artificial chemistries”. We provide a new perspective on traditional issues concerning the design, the formal analysis and the deployment of distributed algorithms and communication protocols, ultimately leading to programmable network dynamics with provable properties. Specifically, (i) we introduce a class of chemistry-inspired flow controllers that can easily be customized to accommodate many requirements of network (resource) management, such as distributed coordination of flow aggregates, capacity allocation, access regulations and service differentiation among user flows or flow bundles. (ii) We show the benefit of the chemical approach in designing solutions to the “distributed consensus problem” for wireless sensor networks. After having designed and analyzed the required interaction rules “on paper”, we use the derived communication protocol in a hardware testbed. Salient features of this minimalistic setup are mainly three. Nodes achieve consensus based only on asynchronously emitted RF pulses. No media access control is used. The protocol works in an embodied fashion by exploiting subtle timing differences and without recurring to symbolic information. (iii) Finally, in order to demonstrate the use of Chemistry-driven mechanisms also for high performance tasks (e.g., high-rate packet-pacing), we describe the implementation of artificial chemistries on an FPGA-based hardware. At the same time, we provide an abstraction for designing runtime-programmable hardware controllers. In this thesis, we use concepts, principles, and theoretical results from Physical Chemistry to engineer communication and networking systems. We focus on system dynamics and exploit laws from chemical kinetics in order to govern the dynamics of a communication network. This is achieved by orchestrating the interactions among network nodes by means of “artificial chemistries”. We provide a new perspective on traditional issues concerning the design, the formal analysis and the deployment of distributed algorithms and communication protocols, ultimately leading to programmable network dynamics with provable properties.
Specifically, (i) we introduce a class of chemistry-inspired flow controllers that can easily be customized to accommodate many requirements of network (resource) management, such as distributed coordina-

tion of flow aggregates, capacity allocation, access regulations and service differentiation among user flows or flow bundles. (ii) We show the benefit of the chemical approach in designing solutions to the “distributed consensus problem” for wireless sensor networks. After having designed and analyzed the required interaction rules “on paper”, we use the derived communication protocol in a hardware testbed. Salient features of this minimalistic setup are mainly three. Nodes achieve consensus based only on asynchronously emitted RF pulses. No media access control is used. The protocol works in an embodied fashion by exploiting subtle timing differences and without recurring to symbolic information. (iii) Finally, in order to demonstrate the use of Chemistry-driven mechanisms also for high performance tasks (e.g., high-rate packet-pacing), we describe the implementation of artificial chemistries on an FPGA-based hardware. At the same time, we provide an abstraction for designing runtime-programmable hardware controllers.

ă

Full Text on edoc ;