Abstract

Nowadays, society and business rely heavily on Information and Communication Technology (ICT) systems. To maintain progress in this regard, research focus is shifting from integration of individual ICT systems into systems which integrate a set of systems into complex systems. This in turn offers enhanced functionality and performance compared to that of the sum of individual systems. In this regard, the concept of Cyber-Physical Systems (CPSs) has emerged in recent years. CPSs are the systems, which combine computational algorithms and communication with physical processes.

The System-of-Systems (SoS) engineering approach has been suggested as a way of modeling complex CPSs. SoS is a collection of multiple, autonomous, and heterogeneous constituent systems, which are integrated to achieve a certain higher goal. A Cyber-Physical System-of-Cyber-Physical Systems (CPSoCPS) then is a specific type of SoS where each constituent system constitutes a CPS. An important challenge in this case is to develop seamless collaboration between the constituent-CPSs to coordinate the operations of several autonomous-yet-interacting CPSs.

In this thesis, we propose a coordination mechanism to coordinate resource allocation and process performance in CPSoCPS. The proposed coordination mechanism constitutes a meta-model of CPSoCPS, intra-constituent optimization model and inter-constituent negotiation model. The meta-model of CPSoCPS describes how multiple autonomous constituent-CPSs are networked together to achieve a higher system goal, which cannot be achieved independently by individual constituent-CPSs. The intra-constituent model describes internal mechanism of an autonomous constituent-CPS. The inter-constituent negotiation model describes how autonomous constituent-CPSs communicate and collaborate with each other in an asynchronous manner through negotiation and also how potential conflicts between constituent-CPSs with conflicting goals are resolved.

The implementation of the proposed coordination mechanism utilizes Controleum [1, 2], which is a generic framework for Multi-Objective Multi-Issue (MOMI) negotiation. Controleum has been extended to support the development of collaborative CPSoCPS, which ensures that the optimization processes in the individual CPSs with autonomous control are coordinated with regards to achieving the group objective for the CPSoCPS.

The efficacy of the proposed mechanism is validated through simulation of different acyclic CPSoCPS topologies which map to real-world CPSoCPS. The results show that the proposed coordination mechanism is able to balance the individual requirements of multiple connected CPSs while adhering to the global goal for an overall CPSoCPS.