This thesis investigates three different resource allocation problems, aiming to achieve two common goals: i) adaptivity to a fast-changing environment, ii) distribution of the computation tasks to achieve a favorable solution. The motivation for this work relies on the modern-era proliferation of sensors and devices, in the Data Acquisition Systems (DAS) layer of the Internet of Things (IoT) architecture. To avoid congestion and enable low-latency services, we need to impose limits on the amount of decisions that can be centralized (i.e. solved in the “cloud”) and/or amount of control information that devices can exchange. This motivated us to develop i) a lightweight PHY Layer protocol for time synchronization and scheduling in Wireless Sensor Networks (WSNs), ii) an adaptive receiver that enables Sub-Nyquist sampling, for efficient spectrum sensing at high frequencies, and iii) an SDN-scheme for resource-sharing across different technologies and operators, to harmoniously and holistically respond to fluctuations in demands at the eNodeB’s layer.
The proposed solution for time synchronization and scheduling is a new protocol, called PulseSS, which is completely event-driven and is inspired by biological networks as heart cells and fireflies. The results on convergence and accuracy for locally connected networks, presented in this thesis, constitute the theoretical foundation for the protocol in terms of performance guarantee. The performance limits, here theoretically derived, provided guidelines for ad-hoc solutions in the actual implementation of the protocol. In particular, we show how propagation delays tend to accumulate over multiple-hops, limiting the synchronization accuracy, and how the topology properties influence the attainable schedules.

The proposed receiver for Compressive Spectrum Sensing (CSS) aims at tackling the noise folding phenomenon, e.g., the accumulation of noise from different sub-bands that are folded, prior to sampling and baseband processing, when an analog front-end aliasing mixer is utilized. In the trade-off between higher accuracy in exploring one band at a time, and faster sensing time in detecting multiple bands simultaneously, we propose a utility maximization approach to find the optimal sequence of tests. We call this scheme the Cognitive Utility Maximization Multiple Access (CUMMA) strategy.

The framework described in the last part of the thesis is inspired by stochastic network optimization tools and dynamics. Typically, the session time $T_s$ e.g. the interval between two decisions, is larger than the interval $T_r$, e.g. the time required for the convergence of the greedy static resource allocation problem. Here we investigate the possibility of using intermediate iterates of each problem instance and anticipate the allocation decisions to gain in adaptivity. This is motivated by the actual network latencies that one has to consider, which following the standard approach, would lead to relatively long session
times, to values longer than what it is possible to implement via SDN-orchestration. While convergence of the proposed approach remains an open problem, the numerical results here presented suggest the capability of the algorithm to handle traffic fluctuations across operators, while respecting an economic constraint, relaxed via Lyapunov drift-plus-penalty approach, to prevent them from gaming the system, i.e. getting more resources than what they have paid for. We call this scheme the Decomposition of Infrastructure-based Dynamic Resource Allocation (DIDRA) scheme.