Abstract

As the Internet-of-Things (IoT) technology continues to mature, organizations are increasingly focusing on developing advanced technologies to draw greater utility from the existing infrastructure. To support innovative applications with stringent quality of service (QoS) requirements, IoT-based services are now being provisioned with the help of distributed *edge-cloud* networks, in which multiple edge and cloud service providers work in conjunction to orchestrate the necessary computation and networking infrastructure. However, the highly dynamic and heterogeneous nature of IoT data traffic and distributed nature of services coupled render the existing network and resource management schemes for edge-clouds inefficient in the context of IoT services. Moreover, numerous IoT services utilize distributed learning with the help of edge-cloud networks. These services introduce additional constraints on the network QoS and hence, require further research attention.

To address the above mentioned issues, we propose service-based network and resource management schemes specially targeting IoT-based edge-clouds in this Thesis. The cooperation and market competition among multiple service providers to provision high quality IoT services adds a new dimension to the problem of network and resource management and is, thus, expected to affect the dynamics of the edge-cloud networks.

In this Thesis, we study the impact of IoT services on the functioning of edge-cloud networks from three perspectives – networking architecture, data handling, and distributed learning strategies. Firstly, we revisit the controller placement problem of software defined networks in the context of IoT-based edge-clouds and propose a game-theoretic solution considering the additional challenges imposed. Thereafter, we analyze the suitability of service-centric networking paradigm for IoT-based edge-clouds and proposed a P4-based implementation of the same. Secondly, for efficient data handling using resource-constrained edge networks, we propose a cost-aware caching scheme which ensures the freshness of IoT data – a crucial QoS parameter for IoT services. We use a contract theoretic approach to achieve the conflicting objectives of the participating entities. Finally, we study the challenges of executing distributed learning using IoT-based edge-cloud networks under both synchronous and asynchronous scenarios. Thereafter, adopting non-cooperative game-theoretic approach, we propose two schemes, for joint resource allocation and incentivization, to address the same.

For performance evaluation, we conduct extensive experiments, both analytical and real test-bed and dataset-based in some cases, and compare the proposed schemes with existing benchmarks. Results demonstrate significant performance improvements in terms of profitability, QoS satisfaction, and resource utilization. Holistically, we observe that the consideration of the cost of resource usage incurred by all involved entities improves profitability without degrading the QoS and resource utilization significantly. However, the lack of information of the actual resource usage cost and that of trust establishment mechanisms negatively impacts the system performance. Such issues can, however, be resolved by the use of Bayesian or probabilistic approaches and the application of blockchain.

Keywords: Edge clouds, Internet of Things, Service-centric Networking, Network Programmability, Caching, Freshness, Federated Learning, Staleness