Abstract

With more than twenty years down the twenty-first century, communication networks are undergoing a paradigm shift. Due to the increase in available computing power, computing-intensive applications in form of augmented/virtual reality, internet of vehicles, remote automation, etc., have emerged in addition to the traditional voice, video, and data. The increasing role of computing in executing applications over networks led to the emergence of cloud, and subsequently edge and fog computing. Next-generation networks are envisioned to be application-driven and designed to satisfy end-to-end (E2E) quality of service (QoS) and quality of experience (QoE) requirements of the applications, considering both network and computing paradigms.

This thesis focuses on achieving the aforementioned goals at the access part of the network that connects end-users to the service providers. The access segment of the network experiences significant dynamic behavior as compared to its core counterpart due to the independent and random nature of users and customers. The thesis investigates two popular access network technologies: Passive Optical Networks (PON) and Radio Access Networks (RAN), in the context of fog and edge computing. While PON is a wired access network, RAN connects to users wirelessly with a wired counterpart from radio stations to the edge/core servers (also known as backhaul). It is desired that fog/edge nodes be integrated with PON in a cost-effective and seamless manner, without altering the protocols in place. In addition, it is important to investigate and design dynamic bandwidth allocation (DBA) policies that can satisfy the strict QoS requirements. Chapter 3 of this thesis, demonstrates how to design a cost-effective fog-integrated architecture for PON. It also delineates a dynamic bandwidth allocation protocol that enables the communication between fog node and users without significantly changing the existing DBA of PON. In Chapter 4, the problem of satisfying strict QoS requirements is solved using the Model Predictive Control (MPC) technique. For this, an innovative delay tracking mechanism using virtual queues is developed,
allowing one to take far-sighted decisions in contrast to short-sighted ones that is commonly employed in the literature.

In RAN, it is envisioned that future networks be zero-touch, implying that the network is able to intelligently automate its policies according to demands, thus significantly reducing human intervention. Orchestrators such as software defined network (SDN) controller (for networks) and Kubernetes (for servers) play an important role as key enablers of a zero-touch implementation. To meet the different QoE requirements of new applications, networking and computing resources are virtualized and sliced-up for each application type, also known as network slicing. To achieve E2E QoE, the two orchestrators should work jointly and create slices of networking and computing resources to satisfy E2E QoE. In addition, they must establish the relationships between E2E QoE and resources so that resource requirements are decided for both deterministic and dynamically changing environments in an automated manner. Chapter 5 of this thesis develops sequential distributed learning and optimization models to learn the relationships under static and dynamic conditions and take robust slicing decisions to achieve E2E QoE at the backhaul of RAN. The learning process requires the incorporation of artificial intelligence (AI) in the slicing process which is a crucial step towards zero-touch network design.

To summarize, this thesis demonstrates how next-generation access network architectures involving fog/edge computing are designed, operated and maintained in an automated and seamless manner.

**Keywords**: Fog Computing, Edge Computing, PON, DBA, QoS, QoE, AI, SDN, Kubernetes.