Control Plane in Software Defined Networks and Stateful Data Planes

Abstract

Legacy telecommunication networks are complex to configure due to the strict coupling of data plane and control plane. In this regard, Software Defined Networking (SDN) is a disruptive technology, which decouples the data plane and control plane, and offers a programmable data plane controlled by a logically centralized SDN controller. This simplifies the network control and provides a complete network view at the SDN controller. One of the key applications of SDN is 5G networks where it is utilized in conjunction with Network Function Virtualization (NFV) to provide end-to-end network service orchestration. 5G networks are being introduced to cope with increasing bandwidth, massive connectivity and low latency demands. SDN is thus advantageous to 5G since it can be used to provision dynamic network connectivity in an automated way. SDN has come a far away since the inception of OpenFlow in 2008, however there are multiple avenues in the scope of SDN to be further investigated. This thesis specifically investigates the control plane of SDN, specifically the various interfaces present in the SDN control plane. Additionally, we present the concept of replicated states in a stateful data plane in the scope of SDN.

As a first contribution, we investigate the east-west interface which carries inter-controller traffic among SDN controllers, so that the SDN controllers have a consistent view of the network. We quantify the impact of the network related data stores (topology, flows and hosts) on the traffic exchanged among a cluster of ONOS controllers. We empirically derive the throughput equation for the inter-controller traffic as a function of the network topology (number of switches and links). We also present the impact of network flows on the inter-controller traffic, the amount of inter-controller traffic based on flow backup for some commercial OpenFlow switches is reported. Furthermore, we also discuss the impact of the host store; where we provide a lower and upper bound on the amount of traffic exchanged between the controllers due to addition of a host in the network.

As a second contribution, in the scope of south-bound interface of an SDN controller, we propose a novel approach using time-synchronized operations (TSO) using timestamps in south-bound extensions in software-defined elastic optical networks. We present an end-of line-scenario in which lightpath rerouting is inevitable to provision a new lightpath. We analytically show that TSO operations executed simultaneously reduce the lightpath disruption time by 75% while rerouting, instead of an asynchronous (ASY) approach, which consists of multiple operations executed separately. Moreover, we present an experimental validation of our approach, where both techniques (ASY and TSO) exhibit close network performance indicators (e.g. OSNR, power budget, spectrum tilt) after the lightpath swapping.

As a third contribution, we utilize the north-bound interface of an SDN controller to provision network connectivity between VNFs in a network service in both inter-domain and intra-domain network service orchestration. For the inter-domain case, we present the 5G UK Exchange (5GUKEx), which is a lightweight network orchestration platform. While integrating various operator platforms, 5GUKEx instantiates network services across different operator domains (islands) and stitches the network services using a common inter-domain network infrastructure. We experimentally demonstrate that the 5GUKEx is lightweight, since it delegates the resource orchestration to the islands. For the intra-domain case, we extend the ETSI-compliant Open Source MANO (OSM) with a Transport-API based WAN Infrastructure

Manager (WIM) connector. This allows connectivity between VNFs running on different PoPs over a heterogenous network.

As a fourth contribution, we present the concept of replicated states in a stateful data planes. We present the argument that instead of using a single state variable which causes congestion and increase of network traffic, replicas of the state must be used to reduce the amount of traffic. We present an ILP formulation of the optimal placement of state replicas and routing of flows through the closest state copy. To solve for larger network topologies, this is accompanied by a heuristic.