Abstract

Software-Defined Networking (SDN) architecture involves separate data and control planes. The SDN data plane consists of switches that store forwarding rules in flow-tables. On the other hand, the SDN control plane consists of controllers that formulate the flow-rules and install or update them at the switches. SDN adds flexibility and programmability to network operations. Due to the additional benefits of softwarization, traditional networks are being migrated to SDN. The intermediate step of transforming a conventional backbone network into pure SDN is termed as hybrid SDN.

The limited storage capacity of switches is a key challenge in SDN, as the switches use Ternary Content Addressable Memories (TCAMs) having very low capacity. Low rule storage capacity eventually leads to a high number of Packet-In messages and control plane overloading. On the other hand, the number and locations of SDN controllers determine the Quality of Service (QoS) parameters, such as network throughput and flow-processing delays. In particular, the placement of controllers is more challenging in hybrid SDN because of additional aspects such as SDN switch placement and incremental upgrades. These challenges increase processing latency and decrease the overall scalability of SDN. Additionally, scalable network operations should ensure optimal energy consumption. However, the lack of centralized control over the power states of legacy switches impedes energy-aware traffic engineering in hybrid SDN. On the other hand, there exists a trade-off between energy-aware routing and programmable traffic as traffic rerouting may transform programmable traffic to a non-programmable one, if not rerouted carefully.

Motivated by these challenges, in this thesis, we propose multiple schemes to enhance the scalability of SDN data and control planes. We propose an approach for consistent update with redundancy reduction that reduces TCAM usage during update. Additionally, we propose a load reduction strategy that prioritizes traffic flows based on QoS demands and aims to avoid link congestion and rule-space overflow during flow migration. Moreover, we apply the concept of tensor decomposition to aggregate flow-rules and increase the available rule-space. On the other hand, we implement a master controller assignment scheme based on IoT devices' mobility and traffic characteristics to prevent controller overload and distribute traffic optimally across the controllers. In addition, we propose a priority-based SDN switch placement approach and a game theory-based

controller placement approach for hybrid SDN. In the final scheme, we focus on reducing energy consumption while maximizing the programmable traffic as it is the primary purpose of transforming a legacy network to an SDN.

Keywords: SDN, Network Update, Flow Migration, Coalition Game, Rule-Space Management, Caching, Markov Predictor, IoT, Hybrid SDN, Controller Placement, Programmable Traffic, Energy Management