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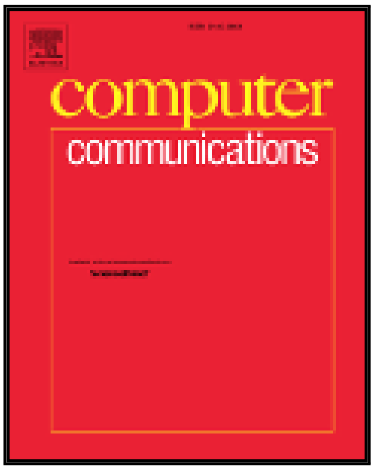

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Capacity and Load-Aware Software-Defined Network Controller Placement in Heterogeneous Environments

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Abstract

Relying upon a single centralized controller in Software-Defined Networks may lead to scalability problems. To make the network scalable and keep latency low for wide area networks, using multiple controllers is proposed. The network is partitioned into some domains, each one is monitored by a controller. However, the number of required controllers, their location and load balancing among them, to prevent controller overloading, have become major challenges in the distributed control plane. Controller Placement Problem (CPP) is widely known as a solution to tackle these issues. Nonetheless, different costs and capacities of controllers should also be considered in solving CPP. In this paper, the problem is formulated as a location-allocation model and our proposed framework solves it in two phases. Regarding different costs of deployment, types and capacities of controllers in the market, the first phase focuses on determining the required number of controllers while minimizing the total cost. Using the result, the second phase is to solve the location-allocation problem to balance the controller load with our introduced fair load distribution function and to reduce inter-controller latency. Two greedy procedures for location and also allocation are designed for our proposed framework algorithms to solve the models and numerical results show their efficiency.

Key Words: Software-defined networks, Controller placement, Load balancing, Fair load distribution, Multi-objective optimization, Anytime Pareto local search.

1. Introduction

Software-Defined Networking (SDN) is a paradigm which separates the control plane of forwarding devices from the data plane and supports programmability of the control plane through northbound and southbound interfaces [1] [2]. The SDN paradigm has emerged over the past few years through several initiatives and standards. It provides flexible network management using centralized and open control. The leading SDN protocol in the industry is the OpenFlow protocol. It is specified by the Open Networking Foundation [3], which regroups the major network service providers and network manufacturers.

A. The Need for Distributed Control Plane

Although a single centralized controller allows for a global view of the whole network, due to congestion, the group of switches which are far away from the centralized controller undergoes higher delays. Recently, there have been several proposals to create a distributed control plane for large SDN networks [4]. Indeed, the control plane, where forwarding decisions are made, is offloaded to more than one controller [5][6] and hence, multiple domains are created. Each controller is responsible for monitoring and controlling switches of one domain for routing, traffic engineering, quality of service, fast failover, etc. The presence of multiple SDN controllers can rise significantly the performance of the network since the load of the network can be distributed among them. Moreover, one controller can take over other controllers when one of them fails. By distributing the load of the network equally among multiple SDN controllers in domains, the network becomes more scalable and efficient [7].

B. The Problem

For further scaling an SDN to the size of, for example, a continent, it is thus necessary to locate multiple controllers at properly selected locations [8]. In fact, partitioning the network into SDN control planes opens many challenges like latency, reliability and load balancing. Given the real assumptions, how to identify the minimum number of required controllers, how to partition the network into several