Multi-objective Optimization Controller Placement Problem in Internet-oriented Software Defined Network

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Abstract

In Internet-oriented Software Defined Network (SDN), the feasibility and scalability are guaranteed by the cooperation among multiple controllers, thus the effective placement of these controllers becomes the significant task. In this paper, we formulate a Multi-objective Optimization Controller Placement (MOCP) problem, which focuses on achieving high network reliability, load balance among controllers, and low latency among controllers and switches. The MOCP covers three specific questions: where the controllers should be placed, how to assign controllers to switches, and how many routing requests should be processed by each controller. We use Adaptive Bacterial Foraging Optimization (ABFO) algorithm and redefine its computation rules to solve the MOCP problem. Simulation results demonstrate that the proposed ABFO based MOCP scheme is effective and has better performance than the existing ones.

Keywords: controller placement, reliability, load balance, latency, Adaptive Bacterial Foraging Optimization

1. Introduction

Software Defined Network (SDN) [1] is a new networking paradigm which emphasizes the decoupling of control plane and data plane, realizes the user customized demands by programmability. SDN moves control logic off packet forwarding hardware, the complex functionalities in network devices are delivered to the specialized SDN controller. As a core component to realize SDN, SDN controller is responsible for maintaining the global view of network and providing the programmatic interfaces to the entire network [2].

A single controller is often sufficient to meet existing response time requirements in many medium-size networks, but only one controller is not enough to manage the whole network with the expansion of network [3]. Furthermore, the physically centralized controller easily causes the single point failure over network, especially the large-scale or hyper-scale network, which significantly limits the reliability of network. If the controller breakdowns or becomes the performance bottleneck, the superiority of SDN will be lost [4]. Therefore, multiple controllers should be deployed and used cooperatively to improve network scalability, provide fault tolerance, and reduce latency of control plane. If one switch is connected to multiple controllers, these controllers can work together to handle routing requests from the switch. Although there are many studies have designed architecture of distributed SDN controller to enhance network scalability [5, 6, 7, 8], it is not efficient to increase the number of controllers merely. Both the number of controllers and their placement locations can affect the network performance significantly, thus it is necessary to investigate the controller placement problem [9]. That is to determine the layout and architecture of control plane, the optimal number of controllers, their locations in network topology, the optimal assignment of controllers to switches, and the optimal workload division among controllers. Heller et al. [9] formally presented the placement problem of controllers in the wide-area networks where the long latency between controllers or controller-switch leads to long response time, and then influences their ability to respond to network events.

In fact, the placement strategy of controllers has many influences on SDN performance [10], such as network reliability, operation cost and response time of events. A controller's failure affects connection between control plane and forwarding plane, breaks down its controlled switches, even disables some functions of control plane. Hence, the controller placement strategy must take reliability into account to improve network availability. When the load of controller exceeds its processing capability, it will suffer more failures because it has no enough resources to deal with all arrived requests from switches. Sometimes this may even lead to the cascading controller failure and increase the overhead of communicating with switches or other controllers, thus how to balance load among multiple controllers is vital. The controller processing latency will substantially increase with the increasing of flows from switches. There are many limitations on network availability, for example, whether controllers can response to network events or

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