University of Victoria | Graduate Studies

Notice of the Final Oral Examination
for the Degree of Doctor of Philosophy

of

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"Resilient Controller Placement Problems in Software Defined Wide-Area Networks"

Department of Computer Science

Tuesday, January 15, 2018
9:30 A.M.
Clearihue Building
Room B007

Supervisory Committee:
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Dr. Sue Whitesides, Department of Computer Science, UVic (Member)
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Abstract

Software Defined Networking (SDN) is an emerging paradigm for network design and management. By providing network programmability and the separation of control and data planes, SDN offers salient features such as simplified and centralized management, reduced complexity, and accelerated innovation. Using SDN, the control and management of network devices are performed by centralized software, called controllers. Particularly, Software-Defined Wide Area Networks (SD-WANs) have made considerable headway in recent years. However, SDN can be a double-edged sword w.r.t. network resilience. The great reliance of SDN on the logically centralized control plane has heightened the concerns of research communities and industries about the resilience of the control plane. Although the controller provides flexible and fine-grained resilience management features that contribute to faster and more efficient failure detection and containment in the network, it is the Achilles' heel of SDN resilience. The resilience of the control plane has a great impact on the functioning of the whole system. The challenges associated with the resilience of control plane should be addressed properly to benefit from SDN's unprecedented capabilities.

This dissertation investigates the aforementioned issues by categorizing them into two groups. First, the resilient design of the control plane is studied. The resilience of the control plane is strongly linked to the *Controller Placement Problem* (CPP), which deals with the positioning and assignment of controllers to the forwarding devices. A resilient CPP needs to assign more than one controller to a switch while it satisfies certain Quality of Service (QoS) requirements. We propose a solution for such a problem that, unlike most of the former studies, takes both the switch-controller/inter-controller latency requirements and the capacity of the controllers into account to meet the traffic load of switches. The proposed algorithms, one of which has a polynomial-time complexity, adopt a *clique-based* approach in graph theory to find high-quality solutions heuristically.

Second, due to the high dynamics of SD-WANs in terms of variations in traffic loads of switches and the QoS requirements that further affect the incurred load on the controllers, proper adjustments to the controller placement are inevitable over time. Therefore, *resilient switch reassignment* and *incremental controller placement* are proposed to re-use the existing geographically distributed controllers as much as possible or make slight modifications to the controller placement. This assists the service providers in decreasing their operational and

maintenance costs. We model these problems as variants of the problem of *scheduling on parallel machines* while considering the capacity of controllers, reassignment cost, and resiliency (which have not been addressed in the existing work) and propose approximation algorithms to solve them efficiently.

To sum up, CPP has a great impact on the resilience of SDN control plane and subsequently the correct functioning of the whole network. Therefore, tailored mechanisms to enhance the resiliency of the control plane should be applied not only at the design stage of SD-WANs but also during their lifespan to handle the dynamics and new requirements of such networks over time.