

A new Framework to enable rapid innovation in Cloud Datacenter through a SDN approach.

José Teixeira

A thesis submitted to the University of Minho in the subject of Informatics, for the
degree of Master of Science, under scientific supervision of Prof. Stefano Giordano
and Prof. Alexandre Santos

University of Minho

School of Engineering

Department of Informatics

September, 2013

Acknowledgments

I would like...

I also...

Abstract

In the last years, the widespread of Cloud computing as the main paradigm to deliver a large plethora of virtualized services significantly increased the complexity of Datacenters management and raised new performance issues for the intra-Datacenter network. Providing heterogeneous services and satisfying users' experience is really challenging for Cloud service providers, since system (IT resources) and network administration functions are definitely separated.

As the Software Defined Networking (SDN) approach seems to be a promising way to address innovation in Datacenters, the thesis presents a new framework that allows to develop and test new OpenFlow-based controllers for Cloud Datacenters. More specifically, the framework enhances both Mininet (a well-known SDN emulator) and POX (a Openflow controller written in python), with all the extensions necessary to experiment novel control and management strategies of IT and network resources.

... talk about obtained results and conclusions(not finished yet, complete when you finish everything)

Keywords: Datacenter, Cloud, SDN, OpenFlow.

Contents

Acknowledgments	iii
Abstract	v
Contents	vii
List of Acronyms	xi
List of Figures	xiii
List of Tables	xv
1 Introduction	1
1.1 Introduction	1
1.2 Motivation and objectives	2
1.3 Dissertation layout	3
2 State of art	5
2.1 Available solutions	5
2.1.1 CloudSim	5
2.1.2 NetFPGA Emulation	5
2.1.3 Meridian	5
2.1.4 Networkcloudsim, Greencloud and icancloud	6

CONTENTS

2.2	Openflow Controllers	7
2.3	Virtual Machine Allocation Policies	8
2.4	Virtual Machine Migration Policies	9
2.5	QoS in SDN	10
3	The Framework	11
3.1	Requirements	11
3.2	Framework architecture	12
3.3	Framework modules: Mininet Environment	13
3.3.1	Topology Generator	13
3.3.2	Traffic Generator	13
3.4	Framework modules: Controller	14
3.4.1	Topology Discovery	14
3.4.2	OF Rules Handler	14
3.4.3	Statistics Handler	14
3.4.4	VM Request Handler	14
3.4.5	VMM - Virtual Machines Manager	14
3.4.6	Network Traffic Requester	14
3.4.7	POX Modules	14
3.4.8	User Defined Logic	14
3.5	Framework modules: Web Platform	15
3.6	Framework modules: VM Requester	16
3.7	Using the framework	17
3.7.1	Emulator	17
3.7.2	Real Environment	17
4	Framework extensions	19

4.1	Enabling QoS	19
4.1.1	QoS in the framework	19
4.2	Enabling Virtual Machine migration	20
4.2.1	Virtual Machine migration in the framework	20
4.2.2	Usecase	20
5	Validation and tests	21
5.1	Framework Validation	21
5.2	Performance Evaluation	22
5.3	Real environment tests	23
6	Conclusions	25
6.1	Main contributions	25
6.2	Future work	25
A	Name of the Appendix	27
	Bibliography	29

CONTENTS

List of Acronyms

DC	Datacenter
SDN	Software Defined Networking
OF	Openflow
VM	Virtual Machine
IP	Internet Protocol
	Add as needed...

LIST OF ACRONYMS

List of Figures

3.1 The framework	12
-----------------------------	----

LIST OF FIGURES

List of Tables

LIST OF TABLES

Chapter 1

Introduction

1.1 Introduction

A Cloud DC consists of virtualized resources that are dynamically allocated, in a seamless and automatic way, to a plethora of heterogeneous applications. In Cloud DCs, services are no more tightly bounded to physical servers, as occurred in traditional DCs, but are provided by Virtual Machines that can migrate from a physical server to another increasing both scalability and reliability. Software virtualization technologies allow a better usage of DC resources; DC management, however, becomes much more difficult, due to the strict separation between systems (*i.e.*, server, VMs and virtual switches) and network (*i.e.*, physical switches) administration.

Moreover, new issues arise, such as isolation and connectivity of VMs. Services performance may suffer from the fragmentation of resources as well as the rigidity and the constraints imposed by the intra-DC network architecture (usually a multilayer 2-tier or 3-tier fat-tree composed of Edge, Aggregation and Core switches [1]). Therefore, Cloud service providers (*e.g.*, [2]) ask for a next generation of intra-DC networks meeting the following features: 1) efficiency, *i.e.*, high server utilization; 2) agility, *i.e.*, fast network response to server/VMs provisioning; 3) scalability, *i.e.*, consolidation and migration of VMs based on applications' requirements; 4) simplicity, *i.e.*, performing all those tasks easily [3].

In this scenario, a recent approach to programmable networks (*i.e.*, Software-Defined Networking) seems to be a promising way to satisfy DC network requirements [4]. Unlike the classic approach where network devices forward traffic according to the adjacent devices, SDN is a new network paradigm that decouples routing decisions (control plane) from the traffic forwarding

(data plane). This routing decisions are made by a programmable centralized intelligence called controller that helps make this architecture more dynamic, automated and manageable.

Following the SDN-based architecture the most deployed SDN protocol is OpenFlow [5] [6], and it is the open standard protocol to communicate and control OF-compliant network devices. Openflow allows a controller to install into OF-compliant network devices forwarding rules which are defined by the administrator/network engineer and match specific traffic flows.

Since SDN allows to re-define and re-configure network functionalities, the basic idea is to introduce an SDN-cloud-DC controller that enables a more efficient, agile, scalable and simple use of both VMs and network resources. Nevertheless, before deploying the novel architectural solutions, huge test campaigns must be performed in experimental environments reproducing a real DC. To this aim, a novel framework is introduced that allows to develop and assess novel SDN-Cloud-DC controllers, and to compare the performance of control and management strategies jointly considering both IT and network resources [7].

TODO:should describe better openflow and SDN

1.2 Motivation and objectives

Although SDN came as a solution to fulfill the network requirements of the DCs, the only point of interaction with the IT resources is the generated traffic. By definition SDN does not go further, but if there could be a controller that manages both IT and network resources, all the information could be shared easily and both of them could greatly benefit: the network could start to anticipate IT actions and adapt itself to have higher performance, more redundancy, etc; the IT because the resources could be better managed so that the network, not only stops being the bottleneck, but actually helps the IT complete the tasks faster and without affecting adjacent resources.

When developing an Openflow controller, the administrator/network engineer goals are to implement the desired behaviour and to test it (making sure it suits the requirements). The currently available controllers already provide some abstraction, which varies according to the type of programming language, but they are still too low level to allow rapid innovation. Following the implementation, tests campaigns must be performed and for it a controlled environment should be set. Although Openflow allows the use of slices of the real network for testing purposes, it is more convenient to use an emulator since the DC size can be dynamic, different scenarios can

be easily produced and it only needs a single computer – Mininet is such an emulator. Despite its flexible API, Mininet is not DC-oriented and does not support any type of traffic generator, which contributes to the deceleration of the development.

Complete with the objectives that "culmatam" estas "falhas". (ultimo paragrafo, mais falar de tudo o que estã para cima)

When the admin wants to try new DC VM allocation algorithms, first it takes to long to develop since the current controllers are still low level, and second if they want to test, or they try on their own DC (which could compromise the normal functioning and unless they try on a small part of the DC the result wont be accurate since they would be influences by the usual workload. Or they would use simulators(the problem with simulator is that usually you have to rewrite the algorithms that you will implement, and the results might not be accurate (correspond to the real environment)). At the same time, a whole framework that provides support to develop and test only the logic that the admin wants would also be cool, since they could focus on making new VM allocations that consider multiple factor (this is where OF helps since it has info about network) Maybe also talk a little about allowing to be easily expandable, extended.

- Understanding the basic features of SDN paradigm
- Studying the problematics in cloud DC VM allocations
- Apply the SDN paradigm to better exploit the DC resources
- Develop a framework for Cloud Datacenter emulation and new VM allocation policies
- ...

1.3 Dissertation layout

In the present Chapter 1 - ...

Chapter 2

State of art

Usually background and related work ...

2.1 Available solutions

Write something generic

2.1.1 CloudSim

Calheiros et al.[6] proposed a Java-based platform, called Cloudsim, that allows to estimate cloud servers performance using a workflow model to simulate applications behaviour.

2.1.2 NetFPGA Emulation

Ellithorpe et al.[7] proposed, an FPGA emulation platform that allows to emulate up-to 256 network nodes on a single chip. However, the cost of a single board is approximately 2, 000 dollars making this solution less attractive than one based on open-source software.

2.1.3 Meridian

Following the new shiny SDN paradigm, Banikazemi et al.[4] proposed Meridian, an SDN-based controller framework for cloud services in real environments: such a platform allows to

create and manage different kind of logical network topologies, but it works on top of a cloud IaaS platform (i.e., Openstack[18], IBM Smart Cloud Provisioning[9]) while our solution is a flexible, standalone software that could even run in a virtualized environment.

2.1.4 Networkcloudsim, Greencloud and icancloud

Other well-known open-source cloud simulators are[13][11] and[19], but in none of them (even in Cloudsim) SDN features are available.

2.2 Openflow Controllers

2.3 Virtual Machine Allocation Policies

2.4 Virtual Machine Migration Policies

2.5 QoS in SDN

Chapter 3

The Framework

Provide the user with a full package for the development and test of DC SDN Controller was one of the main purposes of the framework. Aiming for such goal, but without discarding the deployment in a real DC, a single software environment was designed and developed. Because the requirements change according to the controller being in the development or the deployment phase, so does the environment in order to best suit each of them.

3.1 Requirements

Explain the different requirements in a development & test versus deployment phase.

This environment can be seen as two main components: the DC oriented controller and the DC Topology.

The first one, a full featured python controller for OF switches called POX was used as groundwork. It has ready-to-use modules that are helpful when it comes to making a controller, as they provide some abstraction. However, POX API is too low level for a user that aims to implement a new DC controller, which prevents the rapid development of the logic thought by the user. To fill this gap, the controller available in the framework includes all the abstraction levels needed for quickly building a DC oriented controller while still being fully dynamic.

As for the second component, since performing tests and debug in a real topology can be challenging operations

the starting point was Mininet, a network emulator for SDN systems, which provides an

API to reproduce any kind of topology without the need of hardware resources. Therefore, Mininet enables the assessment of the operation of an OF controller before its deployment in a real environment. Despite its flexibility, Mininet lacks of a complete set of tools that easily allow to emulate the behaviour of a cloud DC, thus raising the following questions:

- How to easily generate and configure typical DC topologies?
- How to simulate VMs allocation requests?
- How to emulate the inter and in/out DC traffic?

3.2 Framework architecture

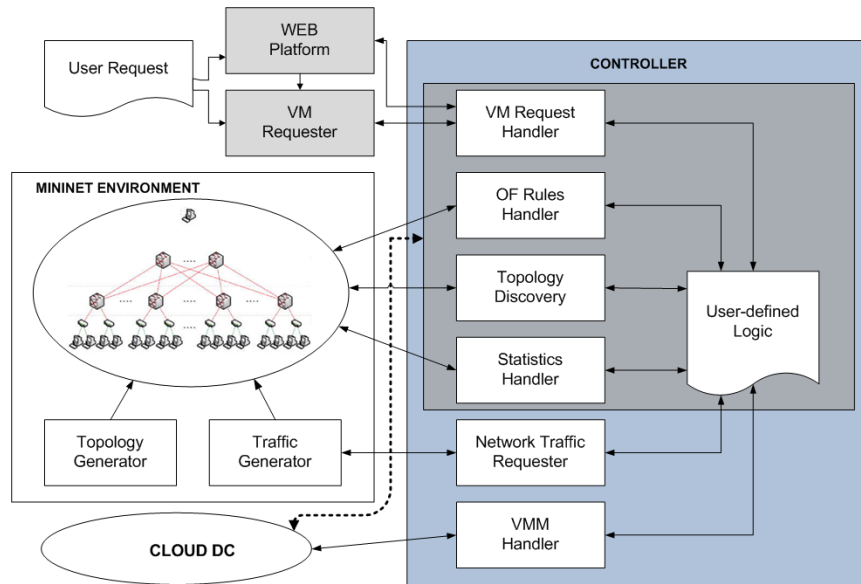


Figure 3.1: The framework

3.3 Framework modules: Mininet Environment

3.3.1 Topology Generator

3.3.2 Traffic Generator

Describe each module, it's functionalities, limitations, how it can be used/improved (improved if the user wants to add new features)

- Talk generally about the traffic generator
- Talk about the one's we tried (pros and cons)

3.4 Framework modules: Controller

Describe each module, it's functionalities, limitations, how it can be used/improved (improved if the user wants to add new features)

3.4.1 Topology Discovery

3.4.2 OF Rules Handler

3.4.3 Statistics Handler

3.4.4 VM Request Handler

3.4.5 VMM - Virtual Machines Manager

3.4.6 Network Traffic Requester

3.4.7 POX Modules

3.4.8 User Defined Logic

3.5 Framework modules: Web Platform

Describe each module, it's functionalities, limitations, how it can be used/improved (improved if the user wants to add new features)

3.6 Framework modules: VM Requester

Describe each module, it's functionalities, limitations, how it can be used/improved (improved if the user wants to add new features)

3.7 Using the framework

3.7.1 Emulator

Describe how to use the framework (emulation part) and how to access the API..

3.7.2 Real Environment

Describe what changes in the real environment (the modules that are disabled and the ones that need to be enabled)

Chapter 4

Framework extensions

4.1 Enabling QoS

4.1.1 QoS in the framework

4.2 Enabling Virtual Machine migration

4.2.1 Virtual Machine migration in the framework

4.2.2 Usecase

Chapter 5

Validation and tests

Usually test and validation of the proposed solution ...

5.1 Framework Validation

- Show how Bf goes against WF with server driven algorithm (show server occupation)
- Show how Bf goes against WF with network driven algorithm (show network occupation)
(although the behaviour is similar is allow to say that net algorithm may use switch statistics)

5.2 Performance Evaluation

Get the tests from the submitted paper.

5.3 Real environment tests

- Talk about the environment which was setup
 - Chosen hypervisor
 - Talk about Xen api and the alternative solution (ssh each server and run a script to clone the vm)
 - OpenVswitches VS NetFPGA problems
 -

Chapter 6

Conclusions

This chapter provides ...

6.1 Main contributions

6.2 Future work

Appendix A

Name of the Appendix

Bibliography

- [1] K. Bilal, S.U. Khan, J. Kolodziej, L. Zhang, K. Hayat, S.A. Madani, N. Min-Allah, L. Wang, and D. Chen. A comparative study of data center network architectures. In *European Conference on Modelling and Simulation*, 2012.
- [2] AWS Home Page. <http://aws.amazon.com>.
- [3] O. Baldonado, SDN, OpenFlow, and next-generation data center networks. <http://www.eetimes.com/design/embedded/4371543/SDN-OpenFlow-and-next-generation-data-center-networks>.
- [4] J. Oltsik and B. Laliberte. Ibm and nec bring sdn/openflow to enterprise data center networks.
- [5] OpenFlow Home Page. <http://www.openflow.org>.
- [6] Open Networking Foundation Home Page. <https://www.opennetworking.org>.
- [7] D. Adami, B. Martini, G. Antichi, S. Giordano, M. Gharbaoui, and P. Castoldi. Effective resource control strategies using openflow in cloud data center. In *International Symposium on Integrated Network Management*. IEEE/IFIP, 2013.
- [8] NS3. <http://www.nsnam.org>.
- [9] Mininet Home Page. <https://mininet.github.com>.
- [10] Openstack Home Page. <http://www.openstack.org>.
- [11] IBM Smart Cloud Provisioning Home Page. <http://www-01.ibm.com/software/tivoli/products/smartcloud-provisioning>.
- [12] POX Home Page. <http://www.noxrepo.org>.

- [13] N. Calheiros, R. Ranjan, A. Beloglazov, C.A.F. De Rose, and R. Buyya. Cloudsim: A toolkit for modeling and simulation of cloud computing environments and evaluation of resource provisioning algorithms. *Software: Practice and Experience*, 41(1):23–50, 2011.
- [14] K. Garg and R. Buyya. Networkcloudsim: Modelling parallel applications in cloud simulations. In *International Conference on Utility and Cloud Computing*. IEEE, 2011.
- [15] J.D. Ellithorpe, Z. Tan, and R.H. Katz. Internet-in-a-box: Emulating datacenter network architectures using fpga’s. In *Design Automation Conference*. ACM/IEEE, 2009.
- [16] J. Matia, E. Jacob, D. Sanchez, and Y. Demchenko. An openflow based network virtualization framework for the cloud. In *International Conference on Cloud Computing Technology and Science*. IEEE, 2011.
- [17] M. Al-Fares, S. Radhakrishnan, B. Raghavan, N. Huang, and A. Vahdat. Hedera: Dynamic flow scheduling for data center networks. In *NSDI*. ACM, 2010.
- [18] R. Raghavendra, J. Lobo, and K.W. Lee. Dynamic graph query primitives for sdn-based cloud network management. In *HotSDN*. ACM, 2012.
- [19] A. Tavakoli, M. Casado, T. Koponen, and S. Shenker. Applying nox to the datacenter. In *HotNets*. ACM, 2009.
- [20] A. Nunez, J.L. Vázquez-Poletti, A.C. Caminero, G.G. Castañé, J. Carretero, and I.M. Llorente. icancloud: A flexible and scalable cloud infrastructure simulator. *Journal of Grid Computing*, 2012.
- [21] M. Banikazemi, D. Olshefski, A. Shaikh, J. Tracey, and G. Wang. Meridian: An sdn platform for cloud network services. *Communications Magazine*, 2013.
- [22] S. Ostermann, K. Plankensteiner, R. Prodan, and T. Fahringer. Groudsim: An event-based simulation framework for computational grids and clouds. *Euro-Par 2010 Parallel Processing Workshops*, 2011.
- [23] D. Kliazovich, P. Bouvry, and S.U. Khan. Greencloud: A packet-level simulator of energy-aware cloud computing data centers. In *Globecom*. IEEE, 2010.
- [24] A. Pescapè, A. Dainotti, A. Botta. A tool for the generation of realistic network workload for emerging networking scenarios. *Computer Networks (Elsevier)*, 2012, Volume 56, Issue 15, pp 3531-3547, 2012.