Resource Management for Software Defined Data Centers for Heterogeneous Infrastructures

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Abstract- *Software Defined Data Center (SDDC) provides more resource management flexibility since everything is defined as a software, including the network as Software Defined Network (SDN).Typically, cloud providers overlook the network, which is configured in static way. SDN can help to meet applications goals with dynamic network configuration and provide best-efforts for QoS. Additionally, SDDC might benefit by instead of be composed by heavy Virtual Machines, use light-weight OS Containers. Despite the advantages of SDDC and OS Containers, it brings more complexity for resource provisioning. The goal of this project is to* optimize the management of container based workloads deployed on Software-defined Data Centers enabled with heterogeneous network fabrics through the use of network-aware placement algorithms that are driven by performance models.

INTRODUCTION

The widespread adoption of cloud is driving the way in which computing solutions are delivered, allowing easier on-demand scaling of resources and pay-as-you-go [1] approaches. While the core of cloud computing shares some ideas with previous approaches like utility and grid computing, its growth and the maturity of technologies like virtualization make it much more efficient in terms of cost, maintenance, and energy consumption [2]. The cloud not only provides automated, large-scale resource management, but it also embodies a different notion of software design. It has the ability to collect, transport, process, store, and access data from anywhere [3], and empowers the use of service-oriented architectures, which are becoming the de facto approach used to increase agility and introduce best practices and patterns.

System virtualization plays a key role in cloud computing platforms, but it is not an entirely new paradigm, some of its foundational research dates back to the early 1970s [4]. The core of system virtualization relies on providing a software layer that appears equivalent to a physical machine. These virtual environments are called VMs (Virtual Machines) and provide the same inputs, outputs, and behavior that would be expected from physical hardware, and can emulate an entire OS (Operating System) [5].

Although virtual machines have plenty of benefits, they also suffer from an inherent overhead introduced by the use of multiple operating system stacks. A possible solution that addresses this kind of overhead and provides a more lightweight virtualization has emerged over the past few years: OS-level virtualization, more commonly called containers [6]. Containers rely on the idea of wrapping, limiting, isolating, controlling, and accounting the resource usage of a set of processes without the need to simulate an entire OS, what results in better performance than VMs and very fast boot times. The design of containers encompasses the idea of processes grouping. This approach leads to a new per-process model for applications, the so-called Microservice Architecture. In such a model, each container represents an independent and small application component that runs its own (few) processes and communicates with other components using a lightweight mechanism [7]. One of the advantages of splitting the application into small components is to efficiently manage each component based on different requirements.

Containers address some problems related to the complexity of Virtual Machines. But this is not the only problem that Clouds facilities need to face: they have overlooked for years the importance of taking into consideration network properties when making workload placement decisions. Anything beyond providing isolation between workloads is usually ignored and therefore deployments are not network-aware, what results in usual problems of performance, application interference, and performance variation [8] due to poor placement decisions. Therefore, workload management is a task that requires the use of control knobs not only for workloads but also for network fabrics.

Fortunately, network management has been making progress over the last years through the development of the Software-defined Networks (SDN) paradigm, which allow for more efficient, flexible and controllable network environments. In particular, SDNs provides very relevant mechanisms for network aware management of workloads, such as resource limits [9], flow control [10] and network slicing techniques [11]. However, since SDN is very new, the integration with cloud management technologies is still on its early stages of development. The success of SDNs in the field of networks has been empowering the growing momentum of more general ”Software Defined Environments” or “Software Defined Everything” environments, in which every component of the Data Center is managed from a centralized software logic. The result is the paradigm of data center infrastructures defined by software (SDDC - Software Defined Data Center), including the network (SDN), storage (SDS) and compute (SDC) infrastructure. More specifically, SDDC allow for the underlying hardware to be utilized as generalized pools of compute, network, and storage [12, 13] resources. There are many aspects of SDDC that boost its resource management, such as the ability to programmatically create, move, delete, snapshot, and restore an entire data center composed of software-defined compute, storage, and network.

In conclusion, the result of the intersection between a strong emergence of SDDCs and the growing momentum of container-based workload deployments in the Cloud is a range of new opportunities for developing new Data Center optimization strategies that need to be studied. And this is the research space that this PhD project plans to cover.

PROPOSAL

The thesis statement of this PhD proposal is the following: **It is possible to optimize the management of container**

based workloads deployed on Software-defined Data Centers enabled with heterogeneous network fabrics through the use of network-aware placement algorithms that are driven by performance models.

For that purpose, the thesis will address three major research challenges further described as following:

- Research Challenge 1: Develop novel performance models for workloads running in containers. Although containers are getting an increasing attention by all major Cloud providers, it remains as an still unexplored space. In particular, this challenge will be split in the following specific objectives:
  - Study of novel designs for deploying applications based on the container per-process models.
  - Build performance models for containers to analyze scalability, overhead and delays associated to their use.
  - Perform a detailed comparative study between deployments based on the use of bare-metal machines, containers and virtual machines.
  - Evaluate and quantify the impact of containers on different representative workloads.
- Research Challenge 2: Develop resource provisioning strategies for workloads run in containers. The strategies will be driven by high-level objectives, expressed in the form of SLAs. In particular, this challenge will be split in the following specific objectives:
  - Design novel SLA-driven provisioning strategies based on user profiles and data center conditions.
  - Build an automated provisioning engine for vertical and horizontal scaling of container-based workloads.
  - Propose machine learning mechanisms to support the provision decision maker based on previously developed performance models.
- Research Challenge 3: Develop network-aware placement algorithms that leverage the previously developed performance models and provisioning strategies. The algorithms will take into consideration network properties (feature-wise and performance-wise) and workload characteristics to optimize the operation of SDDCs. As this is an NP-hard problem, heuristics will be used to provide approximate solutions to the optimization problem. In particular, this challenge will be split in the following specific objectives:
  - Develop heuristics for addressing the problem of making network-aware placement decisions on SDDCs.
  - Build an automated network-aware placement engine, supporting different approaches for provisioning in container-enabled SDDCs.

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