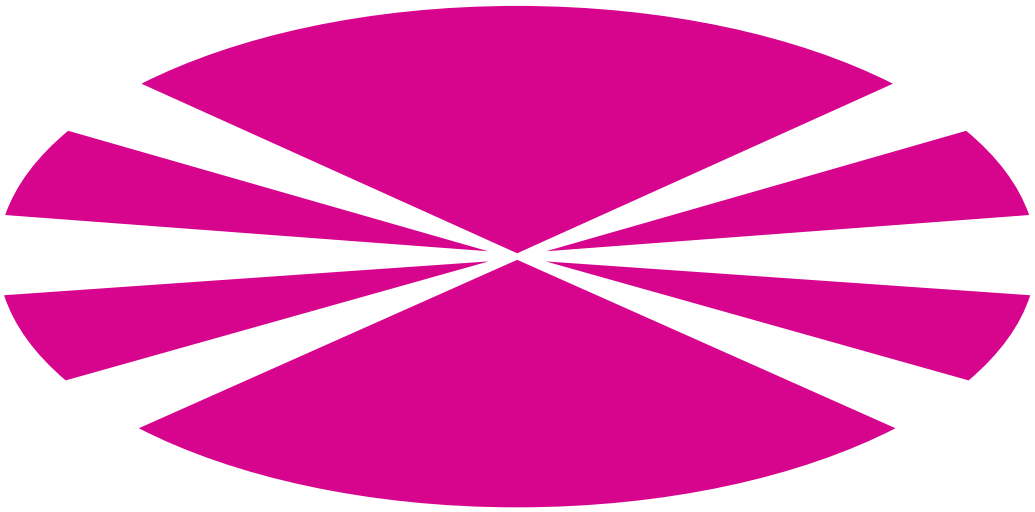

UNIVERSIDADE DA CORUÑA

SCHOOL OF INFORMATICS

Department of Electronics and Systems

Assessment, Design and Implementation of a Private Cloud for MapReduce Applications

Author: Marcos Salgueiro Balsa

Patricia González Gómez

Tutoring: Tomás Fernández Pena

José Carlos Cabaleiro Domínguez

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Give a man a fish, and you'll feed him for a day.
Teach a man to fish, and you'll feed him for a lifetime.
Anne Isabella Thackeray Ritchie

Great spirits have always encountered violent opposition from mediocre minds.
Albert Einsten

The supreme art of war is to subdue the enemy without fighting.
Sun Tzu, *The Art of War*

[...] It takes these very simple-minded instructions – "Go fetch a number, add it to this number, put the result there, perceive if it's greater than this other number" – but executes them at a rate of, let's say, 1,000,000 per second. At 1,000,000 per second, the results appear to be magic.
Steven Paul Jobs

Summary

The history of computation has seen how the technology's unending evolution has promoted changes in its ways and means. Today, *tablets* and *smartphones*, quantitatively inferiors managing and memorizing numbers, camp freely in a global market saturated with options. The tendency is clear: users will get to use more than one device to access the Internet and will like to have all of their data synchronized and at hand, all the time.

But that is only a part in the equation. At the other side of every service request there lays a server that must deal with an ever increasingly troubling traffic volume, while it maintains response delivery at outstanding delay times — low latency "may" have helped the infant Google rise above the competition. If we also added that the idea of surrounding every implementation effort with energetic efficiency is a transcendental requisite and not simply a good practice, we would have a perfect environment for the proliferation of new distributed paradigms as the *Cloud*. The Cloud is not an intrinsically new idea but an old concept abstraction: *virtualization*. The clouds' cornerstone is flexibility.

Another technology that is constantly making it to the headlines is *MapReduce*. If the Cloud centers around easing infrastructure exploitation, MapReduce's core strength lies in its speeding up driving large masses of unstructured data; with makes them an extraordinary computational tandem. This project puts forth a solution that allows for drawing on computational resources available exploiting both technologies together. Special emphasis has been placed in flexibility of access, being a web browser the only application

required to use the service; in simplifying the virtual cluster configuration, by including a self-managed minimum deployment; and in transparency and extensibility, by freeing source code and documentation as *OSS*, favoring its usage as starting point for larger installations.

Keywords

Distributed Computing, Virtualization, Cloud Computing, MapReduce, OpenStack, Hadoop.

Contents

List of Figures

Chapter 1

Abstract

Over the last years there has been a continuous increase in the quantity of information generated with the Internet as the main driver. Furthermore, this information has reshaped from structured — and thus, susceptible to being expressed following a relational schema — to heterogeneous, which has kick-started the necessity to alter the way it is stored and transformed. As the figure 1.1 shows, those that were the undisputed back-end queens — relational database systems mostly — are seeing how their role is fading away due to their incapability to efficiently save unrelated heterogeneity.

As another related dimension, in the year 2000 many .com companies started upgrading their data centers to accommodate the inexorable demand peak that was going to follow. But it never came; and the bubble burst. What happened then was general underutilization — only `10%` of Amazon's global computational resources were in use — that pushed the search for alternative means to export the surplus as a product. Amazon's own initiative unfolded in 2006 with the *AWS* (*Amazon Web Services*) appearance. AWS, among others, implements a public API for flexible on-demand infrastructure provisioning.

Since then, similar projects have proliferated generalizing how private clusters' unused computational capacity is to be serviced, trying to stay API-compatible with the AWS to facilitate interoperability and thus avoid client's

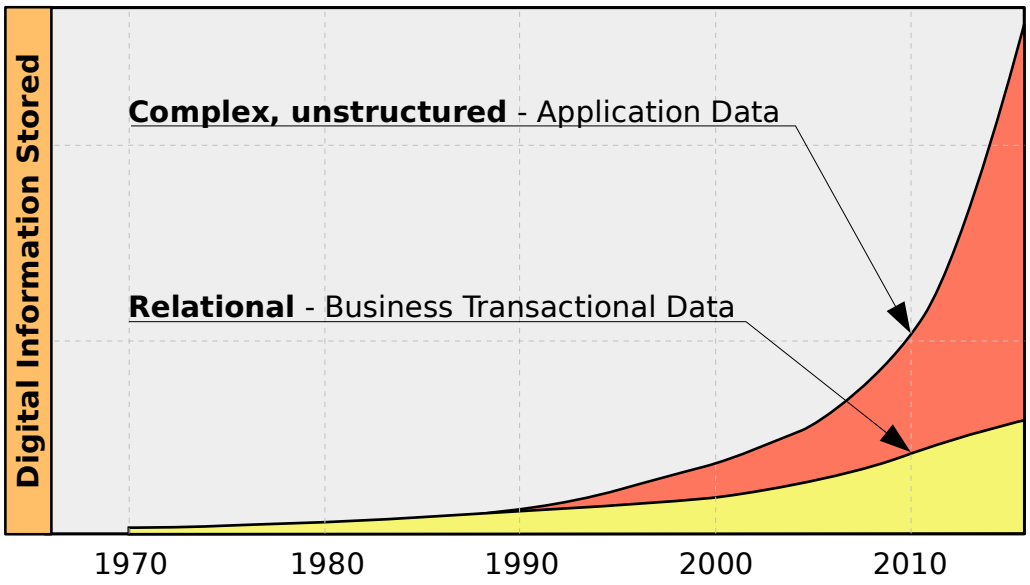

Figure 1.1: Demand in exponential growth. Source: *Cloudera Inc.*

swapping to more flexible providers.

Meanwhile, Google was also in the search for new mechanisms to exploit, with high performance and securely, their own private infrastructure to evolve the capability of their services. MapReduce, as a way to massively execute thousands transformations on input data, became a reality to thrust the generation of Google's humongous inverted index of the Internet [?]. Forthcoming contributions from Nutch's developers — by that time an Internet search engine prototype — to the MapReduce paradigm at *Yahoo!*, would traduce into the appearance of today's *de facto* standard in the field: Hadoop. Nowadays Hadoop is used in a myriad of backgrounds, ranging from travel booking sites to storing and servicing mobile data, ecommerce, image processing applications or searching for new forms of energy.

So, by stacking a MapReduce implementation atop elastic infrastructure an optimal exploitation of computational resources would be attainable, rapidly expanding or shrinking them on-demand, while simultaneously reducing the overall energy consumption required to accomplish processings

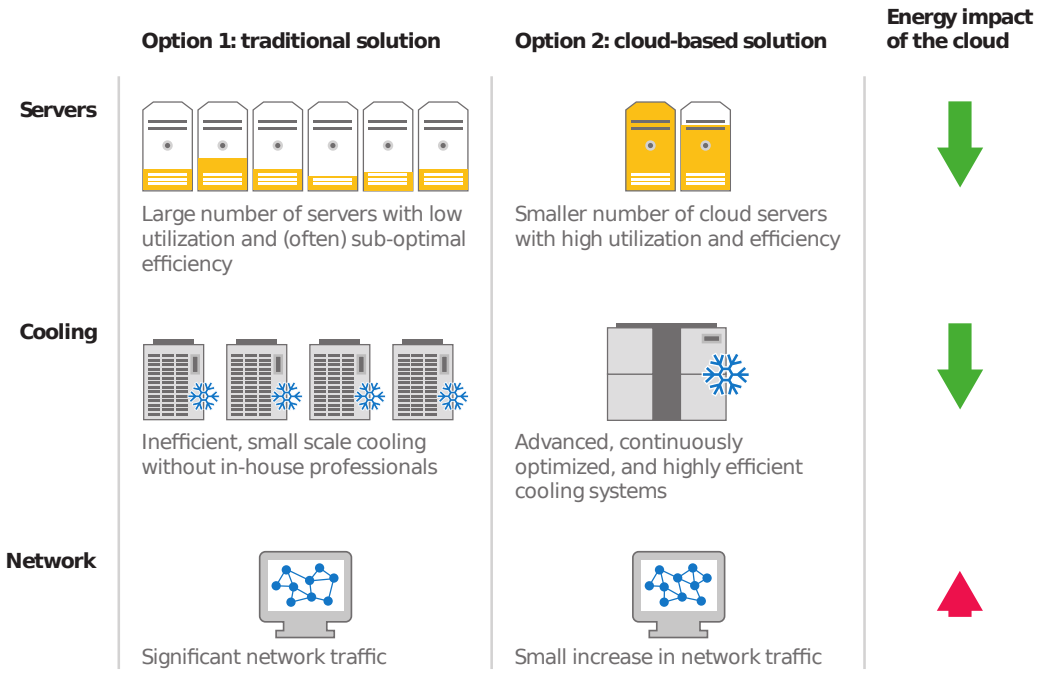

Figure 1.2: Motivación energética. Fuente: [**?**]

(Figure 1.2).

1.1 Goals

El objetivo principal de este proyecto es estudiar la posibilidad de desarrollar una solución que permita dirigir el funcionamiento de un cloud para ejecutar algoritmia codificada siguiendo el paradigma MapReduce, reduciendo al máximo la necesidad de conocimiento de la estructura del cloud concreto utilizado y de los parámetros de configuración de MapReduce.

Para lograrlo se hará un análisis pormenorizado de las variadas soluciones de creación de clouds. Se evaluarán sus capacidades y se configurará un entorno de prueba utilizando virtualización, que permita extraer conclusiones dirigidas a la elección de un *framework* en concreto. Una vez completada la

primera selección, se pasará a la evaluación de los frameworks que soporten las características del paradigma de programación MapReduce.

Asimismo, se desarrollará un mecanismo para el envío de peticiones de ejecución de trabajos MapReduce, centrándonos en la simplicidad y la universalidad de acceso de la interfaz con el cloud y MapReduce. Sin embargo, la sencillez no ha de representar un obstáculo para la explotación y la obtención de resultados. Del mismo modo, tanto la seguridad como la privacidad en las comunicaciones y el almacenamiento habrán de ser convenientemente definidas; no olvidemos que se trata la construcción de un modelo reducido, a escala, de una solución que pueda ser implantable en una infraestructura infinitamente más capaz.

1.2 Organización de la memoria

El contenido del presente documento se distribuye como se expone a continuación. Este primer capítulo introduce la línea general de desarrollo del proyecto. El capítulo **??** acerca al lector conceptos fundamentales de la *computación cloud* —como su arquitectura o la virtualización— y del paradigma MapReduce. El capítulo **??** describe una evaluación práctica de cuatro sistemas de manejo de clouds *IaaS*. El capítulo **??** explora la estructura modular y el funcionamiento particular de OpenStack Folsom. De forma análoga, el capítulo **??** desvela las peculiarias de Hadoop como framework MapReduce.

Los capítulos subsiguientes se centran en detallar el proyecto desde distintos puntos de vista. El capítulo **??** contiene las decisiones de diseño y los diagramas UML. El capítulo **??** recoge los análisis de rendimiento de la solución en un entorno real de pruebas. El capítulo **??** analiza trabajos de investigación experimental relacionados con el proyecto, destacando comparativamente sus características. Finalmente, se resumen las principales aportaciones del proyecto y se proponen futuras mejoras a su implementación.

Adicionalmente se han incluido dos anexos. El apéndice **??** recoge una guía rápida para la puesta en funcionamiento de una instalación del proyecto en un nodo. El apéndice **??** recoge las explicaciones de ciertos términos y tecnologías repartidas por todo el texto.