Chapter 15
Towards Energy Sustainability in Federated and Interoperable Clouds

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ABSTRACT

Cloud federation is paving the way toward new business scenarios in which it is possible to enforce more flexible energy management strategies than in the past. Considering independent cloud providers, each one is exclusively bound to the specific energy supplier powering its datacenter. The situation radically changes if we consider a federation of cloud providers powered by both a conventional energy supplier and a renewable energy generator. In such a context, the opportune relocation of computational workload among providers can lead to a global energy sustainability policy for the whole federation. In this work, the authors investigate the advantages and issues for the achievement of such a sustainable environment.

1. INTRODUCTION

Federation is the next frontier of cloud computing. Throughout the federation, different small and medium Cloud providers belonging to different organizations can join each other to achieve a common goal, usually represented by the optimization of their resources.

The basic idea is that a Cloud provider has not infinite resources. In order to achieve target business scenarios a Cloud provider may need a flexible infrastructure. Federation allows Cloud providers to achieve such a resilient infrastructure asking additional resources to other federation-enabled Cloud Providers. Cloud federation is much more than the mere use of resources provided by a mega-provider.

From a political point of view, the term federation refers to a type of system organization characterized by a joining of partially "self-governing" entities united by a "central government." In a federation, each self-governing status of the component entities is typically independent and

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may not be altered by a unilateral decision of the "central government."

Besides cloud mega-providers, also smaller/medium providers are becoming popular even though the virtualization infrastructures they have deployed in their datacenters cannot directly compete with the bigger counter-parts. A way to overcome this resource limitation is represented by the promotion of federation mechanisms among small/medium cloud providers. This allows to pick up the advantages of other form of economic model considering societies, universities, research centres and organizations that commonly do not fully use the re-sources of their own physical infrastructures.

Moreover, the traditional market where cloud providers offer cloud-based services to their clients, federation triggers a new market where cloud providers can buy and/or sell computing/storage capabilities and services to other clouds. The advantage of transforming a physical datacenter in a cloud virtualization infrastructure in the perspective of cloud federation is twofold. On the one hand, small/medium cloud providers that rent resources to other providers can optimize the use of their infrastructure, which are often underutilized. On the other hand, external small/medium cloud providers can elastically scale up/down their logical virtualization infrastructure borrowing resources of other providers. Federation enables cloud providers to relocate their services in other ones. In our opinion, this allows to plan more flexible energy sustainability strategies than the past.

In this work, we investigate a possible futuristic sustainable federated cloud scenario in which resources are relocated between cloud providers whose datacenters are partially powered by renewable energy generator systems. The federation is seen as a way for reducing energy costs (Energy Cost Saving), but at the same time a possibility to reduce the CO2 emissions (Energy Sustainability).

The main contribution of this work is to investigate the main involved factors that need to be considered for the achievement of such an environment.

The manuscript is organized as follows. The next Section *Background and Related Works* provides an analysis on similar works existing in the literature. Section *Cloud Federation and Energy Sustainability*, introduces how an energy sustainability strategy can be applied to a federated cloud environment. The energy consumption of a datacenter is affected by different factors including the Power contribution for the Information Technology (IT) equipment (PIT), the Power contribution for the Electrical (POW) equipments (PPOW), and the Power contribution for the Cooling (COOL) equipments (PCOOL). To this regards several energy considerations about cloud datacenters are discussed in Section *Power Consumption Considerations of a Datacenter*. Section *Cooling Considerations* deepens how different cooling techniques can affect the energy consumption of a datacenter. In Section *Considerations on a Datacenter Partially Powered by Sustainable Energy: The Photovoltaic Case Study*, we investigate the issues of datacenter partially powered by a photovoltaic energy generator system. In Section *Moving the Computation between Federated Cloud: The Virtual Machine Migration Case Study,* we discuss how a service relocation can take place in federated cloud environment. The last Section summarizes the chapter.

2. BACKGROUND AND RELATED WORKS

In the Section hereby, the early part analyzes works falling into energy saving and green energy topics aimed at datacenter. While in latter part, several works dealing with cloud and federation are reported. In the end, we provide a survey on Green IT solutions aimed at cloud computing.