DOLFIN - Data Centres Optimization for Energy-Efficient and EnvironmentalLy Friendly INternet

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***Abstract*— The optimization of energy consumptions has recently become one of the most critical research topics. At Data Center level, the steady increase of services and functionality is producing huge energy consumption, which needs to be offset in order to respond to the targets of European Union for a share of renewable energy in the range of 10-33% until 2020. The DOLFIN project aims to address the main critical topics related to energy consumption: (i) global optimization of energy usage at DC level, (ii) improve energy stabilization by using a demand/response model to interact with the Smart Grid environment.**

***Keywords*— Energy monitoring, energy management, VM migration, smart grid integration, heat absorption, energy aware SLAs, testbed verification.**

I. INTRODUCTION

Data Centers nowadays are absorbing an enormous and steadily increasing amount of energy, with a significant impact on the environment and the greenhouse emissions. In 2011, Data Center's total energy consumption was around 271 billion kWh, enough to power up all residential households from industrialized countries such as UK or France, comparable to the total amount of energy consumed by Italy [1], approximately 7% of the US total energy consumption [2]. Just the Microsoft Data Center in Quincy (Washington) consumes 48MW, which is enough to power 40.000 homes [3] [4]. The consumption of dozens of MW per Data Center greatly affects the global economy. Modern Data Center may have operational costs as high as $5.6M [5] per year, while in 2010 and 2011 US invested approximately $35 billion in Data Center power consumption. DOLFIN's vision is to significantly contribute towards improving the energy efficiency of Data Center and stabilization of Smart Grids, following a holistic approach, across a network of co-operating Data Centers and Smart Grids.

Today, most DCs are part of computing and storage clouds, offering their customers Virtual Machines (VMs) as a virtual operating environment. Modern virtualization systems provide a method to consolidate multiple virtual machines into fewer physical bare-metal servers, with the aim of increasing the overall power efficiency and lowering operational costs. Anyway, this model presents some degree of inefficiency, due to the lack of DC system orchestration: a logic able to dynamically control the DC assets in accord with continuously changing word load. These assets consist of the management of the physical and logical structure inside the DC (i.e. number active servers, distribution of VMs, etc.) and the business aspects formed by the agreements between the DC owner and their customers (SLAs).

The DOLFIN project introduces such orchestrator. It will model, monitor, and measure energy consumption and enable seamless, autonomic migration of VMs between servers of the same DC or across a group of Energy-conscious, Synergetic DCs, aiming to i) optimize the overall energy consumption by dynamically changing the percentage of active versus stand-by servers as well as the load per active server in a DC, and ii) stabilize the Smart Grid energy distribution by addressing load peaks and increased demand, by dynamically changing the energy consumption/production signature of the local DCs.

DOLFIN also uses the virtualization as a technology enabler to provide more flexible and dynamic SLA (Service Level Agreements) to the DC customers; for example, by providing the possibility of defining service agreements characterized by parameters that can be changed dynamically based on specific business policies that may be directly connected to energy optimization needs.

II. CONCEPT AND OBJECTIVES

To reach the requirements of energy optimization, DOLFIN introduces a complex process to monitor and control the DC activities and resources. This process starts primarily with the definition of a hierarchical structure of macro-functionalities, which defines three distinct realms of optimization..

A. Energy-conscious Synergetic DC-level

At DC level, DOLFIN provides the functionality to optimize the energy consumption within the limits and capabilities of a single DC, by exerting control on virtualization systems in order to achieve an optimal distribution of VMs. This controls the dynamic adaptation of active and stand-by servers and the load per active server. DOLFIN will utilize a new monitoring framework to measure the energy consumption per server module, networking or storage component and will activate low-power states on devices which can be freed of their load. DOLFIN will also complement these energy management mechanisms by prototyping a system for heat reusing for ICT servers, through the use of liquid heat exchangers.

B. Group of Energy-conscious Synergetic DCs-level

DOLFIN envisions the introduction of an optimization model based on the integration of a group of synergistic DCs, cooperating to optimize their cumulative energy consumption signature. The aim is to reach an optimal distribution of VMs across all of the servers belonging to the group of DCs, using policy-based evaluation methods. DOLFIN will measure the energy consumption at the DC level and will employ policies and solutions to that will achieve the lowest cumulative power consumption across the whole group of DCs, while still observing the established service SLAs.

C. Smart City-level

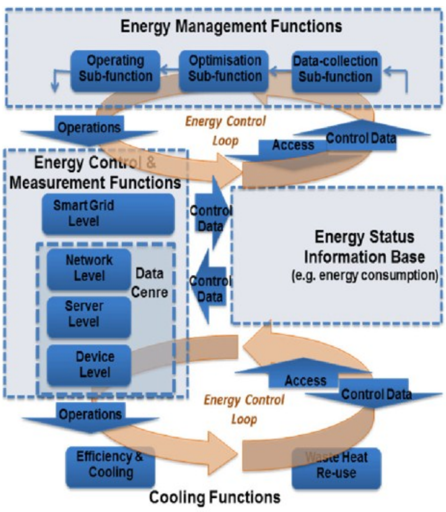
At this level DOLFIN provides stabilization of the local Smart Grid, based on distribution of VMs across the servers that are part of a group of DCs, following an electricity demand-response approach. In order to stabilize the Smart City Energy consumption, DOLFIN will dynamically change the percentage of active versus standby servers per DC to address the Smart Grid availability.

III. DOLFIN OVERALL STRUCTURE

To implement the above three optimization realms, DOLFIN focuses on a subset of elements and procedures, with the objective of: (i) defining/measure/store the data needed to evaluate specific Key Performance Indicators (KPI), metrics used to operate optimization choices; (ii) implementing energy-related policy algorithms; (iii) implementing the interfaces to handle the DC outbound communication (i.e Smart Grid interfaces, DC-to-DC interface, etc.). All these elements need coordination; DOLFIN acts as the “orchestrator” to the overall process of energy optimization. These procedures establish a “closed control loop” as schematized in Fig. 1.

The control loop involves mainly four groups of functions, each of which is in charge of managing and implementing specific requirements and specialized activities.

Fig. 1. DOLFIN Energy Closed Control Loop Functionality



In Fig. 1 are shown a group of coordinated elements that provide the interfaces of the underlying DC legacy subsystems, and also provide new interfaces devised specifically for the DOLFIN environment. A summary of these four groups are described in the following topics:

a) At DC level, the Energy Control & Measurement Functions translate Energy Control choices to actions able reduce energy consumption, as requested by the Energy Management Functions, and perform Energy Measurement by collecting measured status information. These functions are branched into Device-level, Server-level, and Network-level.

b) Energy Management Functions defines the optimal set of operations to be issued to the Energy Control Function and the Energy Measurement Function in order to improve energy efficiency. This includes three sub-functions: a Data Collecting sub-function, an Optimization sub-function, and an Operating sub-function. This high level logic is aware of the DC, Group of Energy-conscious Synergetic DCs, and Smart City optimization realms.

c) Energy Status Information Base encapsulates a database storing basic information about the current DC status. It contains a set of status information such as energy consumption, environmental factors or sustained work load.

d) Cooling Functions, which control the thermal efficiency of DC and manage the waste heat reuse.

IV. CONCLUSION

DOLFIN’s aim is to drastically improve current DC energy efficency as well as establishing viable interfaces allowing inter-DC cooperation, dynamic SLA renegotiation and workload redistribution, which are feats currently not embodied by the established practice. This will allow existing and new DCs to improve their energy absorption signature, to better adapt to load peaks, and to contribute to the local Smart Grid stabilization.

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