GreenSLAs
Providing Energy Consumption Flexibility in DCs through Energy-aware Contracts

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Abstract: This paper describes how eco-motivated extensions added to the traditional SLA concept can provide levels of flexibility in the data centre management that enable the data centre to reduce the energy consumption, improve the environmental footprint and lower internal costs. A close collaboration with both the IT customer and the data centre's energy provider are key to this approach which is formalized by means of the GreenSLA concept building on the three main components: Flexibility, GreenKPIs and collaboration. Performance decisions regarding the energy consumed by the services are taken and translated to actions to be executed to save energy while at the same time guaranteeing the contract agreements.

1 INTRODUCTION

Electricity consumed in DCs, including enterprise ICT equipment, air cooling devices (AC) and uninterruptable power supply systems (UPS), is expected to contribute substantially to the electricity consumed in the European Union (EU) commercial sector in the near future, especially with the cloud computing trend still on the rise.

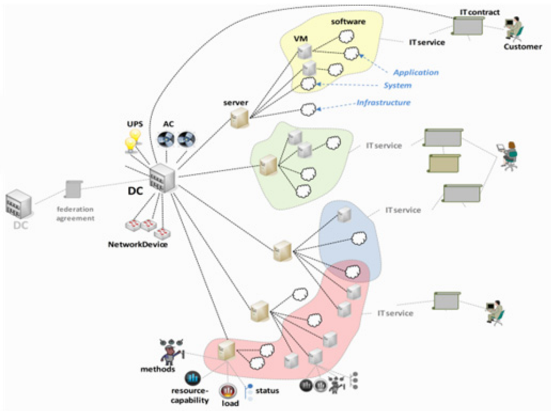

Figure 1: IT Service.

The project All4Green analyses the relationship between the IT Customer (ITC) and DC (DC) or DC federation in conjunction with the relationship between the DC and the EP (EP), aiming to unlock the untapped potential for globally saving energy and CO2 emissions by proposing enhanced collaboration mechanisms within the DC ecosystem.

New flexible contracts (Green-SLAs) between IT users and DCs are used to enable efficient energy saving policies tailored to different computing styles and to enable a better matching of DCs energy demand profiles with energy supply patterns of the EPs.

2 GreenSLAs IN ALL4GREEN

The liabilities between a DC and its customers are ruled by a set of contracts. Apart from framework contracts, for the delivery of each DC service a service level agreement (SLA) is closed. In the context of this paper we state that in a DC an arbitrary collection of **servers**, **software** and **VM entities** jointly provide an IT service to end-users as shown in figure 1.

The SLA that is connected to each service contains at least a subset of the following elements:

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A functional description of the service, performance requirements, availability, maintenance work plan, specific execution requirements, financial penalties and rewards.

As DCs deliver an abundance of IT services with as many SLAs to be monitored and executed, the formal WS-Agreement framework has become a *de facto* standard in research projects due to its flexibility in integrating agreement-specific elements.

The WS-Agreement is denoted in XML and is made up of the following building blocks as depicted in figure 2: Name, context, and terms. Within the terms, service terms are definition and description elements whereas guarantee terms provide metrics based on the definitions in the service terms and indicate the contracted boundaries for these metrics.

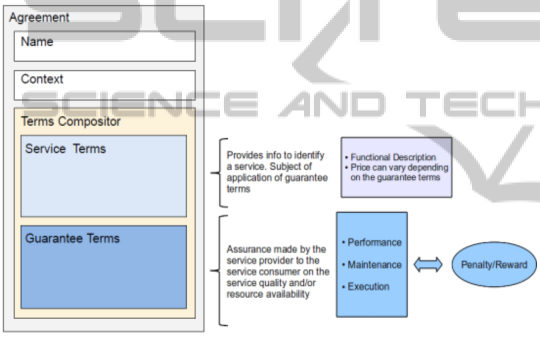

Figure 2: WS-Agreements.

Until now, however, SLAs were very static in nature and restricted to a very function point of view. As the environmental impact of IT services all over the world needs to be reduced, the idea of an eco-motivated SLA, a so-called GreenSLA was developed.

3 GreenSLA

Previous research has been made in the context of GreenSLA (Laszewski and Wang, 2010), (Klingert et al., 2011) considering the DC as an atomic unit. However, All4Green goes one step further by including the main actors of the DC's ecosystem with EP and ITC. In All4Green, GreenSLAs are extensions to traditional SLAs including three main additions:

- *Flexibility*,
- *GreenKPIs* and
- *Collaboration*

The *flexibility* is the variability that the ITC and the DC are willing to accept in each of the service's running conditions requirements (e.g. performance/ availability/execution/maintenance) due to a change in the context. The context can be defined as the specific situation that provokes the possibility of modifying the service conditions to promote a more environmentally friendly behaviour. The time span and context dependency of these situations should lead to the reduction of energy consumption or CO_2 emissions while executing a service. For instance, a time-dependent IT service can work at high performance level from 8am to 10pm and decrease to low performance from 10pm to 8am.

Similarly, *green KPIs* are new service level objectives also pursuing the goals for energy consumption and/or CO_2 emission reduction. For instance, a GreenSLA could guarantee a certain CO_2 emissions level during the execution of an IT service by allowing continuous interaction between the DC and the EP.

Collaboration in the DC-ITC sub-ecosystem is regulated by the GreenSLA and refers to the requests to the ITC coming from the DC. These requests are triggered by the change of the DC mode: From regular mode the DC might switch to situations where it needs to reduce its current energy consumption (energy saving mode) or, on the contrary, switch to a situation where it needs to consume extra available energy (extra energy mode). This change of DC status comes from the interaction of the actors in the DC-EP sub-ecosystem.

3.1 Flexibility

Flexibility will depend on a predetermined context. This context is the situation and the condition in which the guaranteed level of a determined service item can be modified in order to effect energy and/or CO_2 emissions savings. GreenSLAs differentiate between two different context types: time/calendar-dependency and energy DC mode-dependency.

Time/Calendar-dependency: This context is related to a time period: hour(s) and/or day(s) of the week and/or the year's season. As mentioned above, an example of a time-dependent GreenSLA clause could be: *High Availability + High Performance* in working days, and low availability + low performance during nights and weekends.

DC Energy Mode-dependency: As shown in figure 3, this context is related to the current energy mode of the DC. Generally, the DC is in Regular Energy mode (RE), but it can change to Extra Energy (EE) mode or to Energy Saving (ES) mode for a certain time period due to the reception and acceptance of a request coming from the EP.

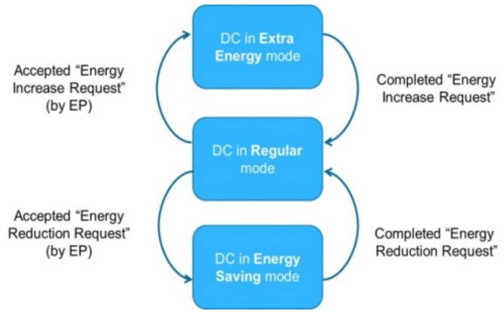

Figure 3: Possible Datacentre States.

In ES mode the DC attempts to save energy by, amongst others, downgrading IT services and/or shifting tasks in time, whereas in EE mode the DC could promote IT services to higher performance levels, or anticipate the execution of maintenance tasks. GreenSLAs should offer flexible clauses to regulate and support this behaviour. For example, an energy mode-dependent GreenSLA clause could be: *Medium performance + medium availability* in regular mode and *Low performance + Low availability* in ES mode.

3.2 GreenKPIs

GreenKPIs have the double function of monitoring the eco-sustainability of a service and giving feedback to the ITC that the GreenSLA guarantees a win-win situation not only from the economic but also from the environmental point of view.

Examples for GreenKPIs can be a guaranteed energy mix for the DC or a boundary for CO2 emissions generated or KWh consumed by a certain service.

3.3 Collaboration

The **Collaboration level** between DC and ITC is tightly (but not exclusively) bound to the existing collaboration agreements between EP and DC. This means that the DC knows its degree of commitment with the EP before setting up GreenSLAs with its ITCs.

A collaboration request sent from the DC to the ITC is generally originated by the EP-DC collaboration. As shown in figure 4 the EP can request a reduction of energy consumption or may demand higher energy consumption due to a surplus of renewable energy. In order to accept this request, the DC may initiate a negotiation with the ITC by requesting the permit to execute a set of actions that modify the current behavior of the IT service.

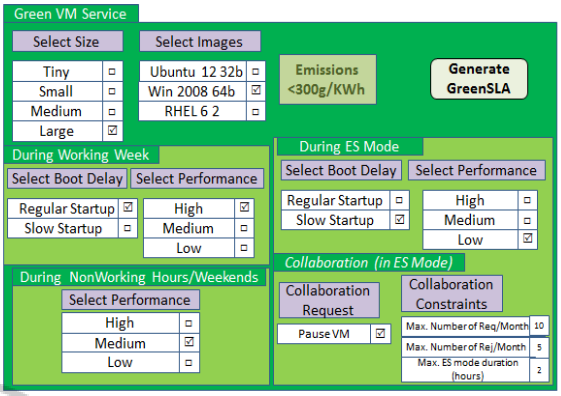

Figure 4: Cloud GreenSLA template.

An example is to ask the ITC if a VM can be paused for e.g. 2 hours – the response very likely depends on the current status of the application running inside the VM (that is known to the ITC, but not to the DC).

Upon the reception of a collaboration request, the ITC has the freedom to reject but also the obligation to accept a certain number of times. Otherwise it loses its right to an economical reward. GreenSLAs also regulates the degree of freedom of the ITC Agent and the voracity of the DC.

3.4 Pricing

It is the basic principle of GreenSLAs that the ITC renounces pre-specified performance aspects in order to receive a reward in return. This is the incentive aspect of GreenSLAs which was described, e.g. in (Klingert et al., 2011), (Bunse et al., 2012). The incentive can be either financial or non-financial like e.g. a special treatment for green customers, or a combination of both. In All4Green, a purely financial incentive was chosen, as most of the use cases involved a B2B-relationship between DC and ITC.

Generally, the pricing of an IT service depends on a fix basic fee and variable components, like transaction fees and prices per service instance.

To fulfil the incentive function the expected GreenSLA reward must to a great degree surpass the expected GreenSLA penalty. The reward in All4Green depends on the (contracted) flexibility that the IT customer agreed on in the GreenSLA, the (measured) QoS degradation the ITC has to endure, and the (measured) collaboration effort between the ITC and DC. The contracted (ex-ante) part of the reward by nature is static in the way that it composes an unchangeable (and thus reliable) part of the reward as long as the contract, the GreenSLA, is valid. The measured (ex-post) parts of the reward by nature are dynamic in the way that they change along with the behaviour of the customer as well as the technical implications of the activity of the DC management within the All4Green framework. Thus the reward formula can be expressed as:

GreenSLAReward=StaticReward(Flexibility)+DynamicReward(ΔQoS,realizedCollaboration)-Penalty(realizedCollaboration)

Penalties are imposed in case the ITC's collaboration is lower than contractually agreed.

4 EXAMPLE

This section presents an example of GreenSLA for a simple IT service offered by a cloud provider. Cloud computing services mainly consist of VMs and include KPI detailed parameters such as Boot delay, computing power, memory, OS image, I/O performance or disk size. For the sake of simplicity, a subset of the offered service portfolio is provided:

- VMs have "*sizes*" composed of a pre-determined number of virtual CPUs (VCPUs), RAM and HD capacity.
- VMs run "images" of Operating Systems.
- The *Performance* KPI limits in equivalent percentage of CPU units (ECUs).
- The *Boot delay* KPI limits the start-up time.

A template that generates a GreenSLA for the Green VM service as described in this section is shown in figure 4: It represents the renting of a VM with a large size and Windows 2008 and the following specific arrangements for the GreenSLA parameters:

As stated in the previous section, the flexibility depends on the time/calendar and DC energy mode. In this example, the time/calendar-dependency makes evokes very flexible scheduling. Additionally, the DC energy mode dependency enables a flexible boot delay and performance.

Concerning a GreenKPI, in this example, the CO2 emissions, retrieved through the EP of the DC, are limited: i.e. the energy provided by EP to DC should be produced at **<300g CO2/Kwh**. If this guarantee is breached, a penalty must be paid by the DC. Concerning collaboration additions, this GreenSLA allows requests coming from the DC that ask to pause the VM for a maximum of two hours. The collaboration limitations in this example are defined as follows: The DC can issue a maximum of 10 collaboration requests per month to the ITC, and the ITC can reject a maximum of 5 collaboration requests per month.

5 EXPECTED ENERGY SAVINGS

The energy savings in the DC due to the GreenSLA contractual terms related to the collaboration with customers are expected to be approximately 10% according to the estimations and trials done so far in the All4Green project. The EP will be able to avoid dangerous peaks, thus avoiding large costs and reducing emissions. These cost savings will be partially used to compensate the collaborating data centers, and in the end this will generate a positive side effect for the ecosystem, both from Energy/emissions and economic point of view.

6 CONCLUSIONS

This paper has presented the three main components of the GreenSLA concept (flexibility, GreenKPIs and Collaboration) and how the DC takes performance decisions regarding the energy consumed by the services to save energy compared to ecosystems that not include these concepts, while guaranteeing the contract agreements. All4Green implementation details and a practical example have been provided.

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