Methodology for Green Certificates of Service Applications

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***Abstract*— Energy-aware services can be obtained by composing Green Performance Indicators (GPIs) into a Green Certificate (GC), a document showing a service's energy-related performance along all the service lifecycle. This paper describes a methodology to create the GC and to use it for service selection and in service-based business processes.**

Keywords: Green computing, Service Systems, Green Performance Indicators, Green Certificate, Methodology for Green Services

Introduction

In order to introduce new development and execution paradigms oriented to service applications aware of the energy they consume, a methodology for service development and use including energy-related performance indicators is needed [1]. In such a methodology, services should be characterized in terms of the employed (and wasted) energy during their lifecycle. An *energy-aware service* can be featured through "green" metrics [2] given as annotations about service development, execution and maintenance. Green metrics, called here *Green Performance Indicators (GPIs)* characterize a service under various aspects: the use of the IT infrastructures, the Quality of Service (QoS), or environmental aspects. GPIs can be grouped to form a *Green Certificate (GC)* for the service, which, at a high level of definition, specifies the relationship between sustainability and ICT. In this paper, we propose a methodology to create and use GCs for services. The methodology defines a GC as a tradable commodity for service providers and consumers. The GC shows energy-related performance of a service from the *technical* view (IT or provider's production perspective) and from the *organizational* view (business or customer's use perspective). The methodology contains steps for GC creation, publication, use, and disposal. It allows providers to specify energy profiles of their services and consumers to select services from service registries taking into account energy–related criteria. The GC is computed out of GPIs and is published to certify the level of energy consumption (of "green-ness" of a service). We rely on our previous work on GPIs [3]. After reviewing the GPIs, the paper proposes the methodology in four steps: creation, publication, use-disposal of the GC. The methodology is framed in the EU-FP7 GAMES Project [1], which develops methodologies, software tools and services, and innovative metrics for an energy-aware design and management of the service centres [1, 3]. Section I presents related work. Section II describes the concept of GC and details its structure. Section III presents the methodology for creation and use of GCs. Section IV draws conclusions and future work.

I. RELATED WORK

Research on *metrics* for green IT and data centres focuses on evaluating energy consumption of applications and data centers and hence to achieve economic, environmental, and technological sustainability. Several metrics measure data centre efficiency, proposed by Green Grid, Uptime Institute, Transaction Performance processing Council (TPC) and others. No accepted metric set is available. In [4] server energy efficiency metrics are presented, with requirements for new metrics considering Green IT as a technology to be harmonized as a hardware, software, architecture, and QoS solution. On the other side, the California Green Business Program [5] lists a set of metrics for measuring environmental benefits of Green Business Practices. However, the scope of these metrics considers almost only elements in the business context. An approach to certificates is proposed in [6] for large-scale distributed systems in the frame of the GREEN-NET project where certificates are addressed for trust purposes. Some proposals are guided by societies' and governmental efforts worried about the impact of IT equipment on the environment. [7] explores the relationship between IT Service Management and Green IT referring to the British Computer Society guidelines which include Green IT regulations, legislation and policy, identification and base-lining of current Green IT credentials, and advices on how to move forward in delivering Greener IT [8]. In [9], a document developed by BSI British Standards, BSI PAS 2050 is indicated as a publicly available specification for assessing product lifecycle greenhouse gas emissions and giving cues for green certificates for services, including software services. Software methodologies, designs, and software development tools that can be employed to enhance the energy efficiency of applications in mobile systems are examined in [10].

[1] http://www.green-datacenters.eu/

Based on studies on software sustainability, [11] states sustainable software engineering issues. A proposal for a lifecycle model helping to develop green and sustainable software is presented in [12]. While these papers address software engineering methods in general, we focus on service-oriented applications.

II. GREEN CERTIFICATE

We assume that a GC refers to *one service* and is expressed as a *cost per invocation*. The *use of the GC* is based on a *comparison* among functionally equivalent services. In fact, it is hard to specify a GC as an absolute measure of the green-ness of one service. In contrast, GCs can be used more simply when searching for a service from a *business* viewpoint and comparing the different services from the sustainability viewpoint. Considering a service S_i, GAMES GPIs are annotations for S_i structured in four clusters (details are in [13]): i) IT resource usage metrics; ii) Lifecycle metrics; iii) Energy impact metrics; and iv) Organizational metrics (regarding regulations and/or consortium policies (Energystar [2] and Environmental Protection Agency[3]).

A. GC Structure

A GC comprises three sections: Issuer Declaration, GPI Catalog and Valuation (see model in Fig. 1). The IssuerDeclaration section is a placeholder where the GC's issuer inserts his name, contact, and a signature to guarantee integrity and authenticity during the valuations. To this purpose, we have integrated our proposal for GC definition with the XML Data Signature W3C standard[4]. The GPI Catalog section contains the definitions of GPI Clusters and single GPIs that will have an assigned value in the GC. The catalogs can be stored in separate documents and referenced from multiple certificates. In order to demonstrate this feature, we have created a GPI catalog for GAMES[5]. Each GPI in the catalog has a measuring and monitoring guidelines field, describing how the GPI value should be computed, including the factors that contribute to its value, and a measurement units field. The Valuation section of the GC specifies the values for the GPI, its aggregation by clusters; also the global cost values are provided. In order to support a consistent definition of the GPI values along the GC, and a meaningful cluster and global aggregation, we express the GPI values in terms of costs per service invocations.

III. METHODOLOGY FOR GCS

The methodology is composed of four phases: i) Creation; ii) Publication; iii) Use; and iv) Disposal. The lifecycle of a GC is closely related to the model of service-based interaction: publish-find-bind-execute. In this sense, the GC is published along with the service contract to help consumers in finding the most convenient service for binding (taking into account their green-ness).

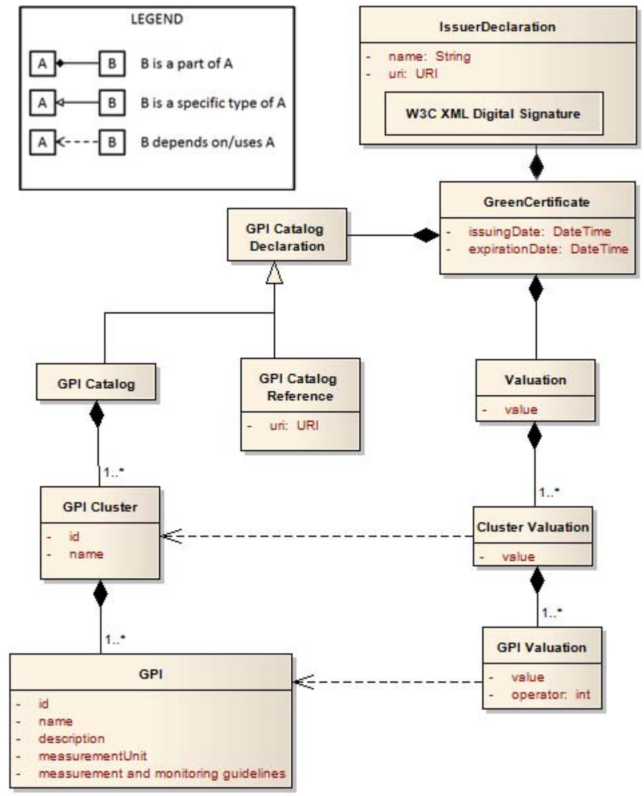

Figure 1. UML meta-model of Green Certificates

The *steps* of the lifecycle and the actors that interact with the GC in each step are:

1. *GC Creation*. The *Service owner/provider* generates a GC for S_i. The actor's responsibilities consist in aggregating the GPIs required in conformity with green regulations. This actor has to inform other actors about any changes that could alter the validity of the GC and possibly revoke the GC.
2. *GC Publication*. The GC of S_i is made available to potential users for evaluation of energy consumed when using S_i. The involved actors are: a) *Trust Authority*. It validates information in the GC according to a set of data about reputation, trust, etc. collected in the network. The same stakeholder can play different roles along the GC lifecycle. For example, depending on the trust model, the trust authority and service provider can be the same organization. b) *Publication targets*. They make the GC available along with the information needed for service discovery and use.
3. *GC Use*. The objective is to enable the analysis of the GC by service providers in order to improve its green-

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[2] http://www.eu-energystar.org
[3] http://www.epa.gov/
[4] http://www.w3.org/TR/xmldsig-core/
[5] http://www.isa.us.es/uploads/GAMES/CanonicalGPICatalog.xml

ness, and the selection of services to be invoked by potential users, taking into account information in the GCs. The involved actors are: *Service Consumers* and *Service providers*.

4. *Disposal*. The objective is to avoid the use of a GC after its expiration date or when any circumstances that invalidate the GC have been detected. The involved actors are: *Service providers*, *Publication targets* and *Service Consumers*.

Fig. 2 shows the GC lifecycle as an UML activity diagram. The actors' hierarchy represents the different types of publication targets that could interact with the GC, namely: service registries, web portals and application servers, and middleware platforms, such as enterprise service buses (ESBs) or SOA governance platforms (e.g. the WSO2 Governance Repository [14] or Mule Galaxy [15].

A. Creation Step

The activities in the step of creating a GC for a service S_i out of its GPIs is as follows.

A1 Identify the applicable GPIs using a GPI catalog. The first activity is the identification of the GPIs that will be included. The set of GPIs strongly depends on the specific business context and implementation of the service. This activity starts with a search for standards and regulations about sustainability in the given business context. Existing GCs of other service providers can also be useful as a reference. If no standards (or no other GCs) exist, then, the GAMES GPI catalog can be used as a starting point. Different catalogs can exist for given business areas. It would be recommended that a standard catalog exists, at least for business areas, so that GCs are comparable. We assume that GCs are defined starting from the GAMES catalog as a stable reference. Additionally, in some scenarios, providers could add GPIs relevant for their services. A catalog has a long lifecycle; if it is changed, there will be a notification to users in terms of a new version or evolution of the catalog with the consequent need to update the GCs. The GPIs in the GAMES catalog document are domain-independent and are applicable to nearly any business service provided though an IT infrastructure. More generally, those organizations that have set up standards for environmental management, such as ISO 14001 [16], are likely to use the database of environmental aspects defined in such standard. As a result of this activity, an initial version of the GC is created.

A2 Identify inputs for each applicable GPI. This activity identifies the business procedures that contribute to form the value of each GPI. The starting point is given by the service provisioning and delivery procedures of the organization. Support and auxiliary processes, such as IT infrastructure management, control and maintenance, as well as the service development process might also be taken into account. Organizations which specified a clear processes map and those following IT management methodologies such as ISO/IEC 20000[6] or ITI[7] can take advantage of them in this activity. If a new GPI catalog is created, the set of relevant factors used for computing each GPI could be specified in the *Monitoring and Measuring* attribute of the GPI (see Fig. 1) generating a new version of this artefact. Otherwise, details will be described in an internal version of the document to be used along the GC creation process. Factors identified for the Consumables Index GPI are consumed papers, toners, equipment and consumables used in service maintenance, user support and monitoring.

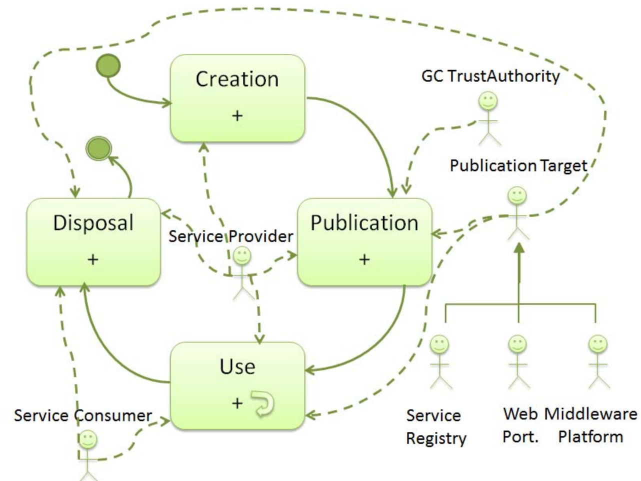

Figure 2. GC lifecycle phases and involved actors

A3 Identify information sources that can provide the input values for each GPI. For each GPI, the metrics, the GPI monitoring system, and the information sources available for its measurement are selected. Organizations that have implanted BPMS (Business Process Management Systems) can take advantage of the system-embedded monitoring and KPI-measurement capabilities. A useful technique is the definition of annotations of the BPMN diagrams defining process metrics and indicators that will be used as inputs for the computation of the GPIs. For some GPIs, some issues can neither be obtained from valid quantification data source nor an approximate estimation can be given. This needs a decision: either exclude the affected GPIs from the GC or assume that the impact of those factors is not significant for the GPI, and hence ignore the factor. If a new GPI catalog is created, the output of ***A3*** is an improved version of the GPI catalog, where the *Monitoring and Measuring* attribute of the GPIs (see Fig. 3) is augmented to illustrate the decisions made at this step.

[6] webstore.ansi.org
[7] www.itil.co.uk/

TABLE 1. INPUT DATA AND THEIR MEASUREMENT UNITS FOR THE CONSUMABLES INDEX GPI OF A SERVICE.

Consumables Index GPI			
Factor	*Value*	*Measurement Units*	*Measurement Interval*
Paper	6	Number of Paper Sheet Packages. Mapped into costs considering the average annual price per sheet package (or using invoices).	Quarterly
Toner	2	Toner Units. Mapped into costs (using invoices).	Quarterly
Other	300	Euros.	Annual

A4 Retrieve and collect input data. The specific values for each GPI are collected to compute their aggregations by cluster and the GC. At this point, some metadata needs to be retrieved about the value collected for each factor, such as the set of services to which the factor (and its associated activities and business processes) provides support, the measurement units of the factor, and the time interval along which the values are measured. ***A4*** requires taking into account the measurement guidelines specified in the GPI catalogue. Data collected during this activity could be required by a Certification Authority to validate the GC in the subsequent activity (see ***B4***) of the publication stage. Table 1 shows the input data and their measurement units for the *Consumables* Index GPI of a service.

A5 Compute valuations and enact GC. As an assumption, GPI are expressed as *costs per invocation of the service*. Hence, the obtained values have to be normalized to be able to compute the global valuation as a simple sum. For such normalization, some constants should be defined as follows.

1) *GC Computation Time Interval* (CTI): time interval during which the factors affecting GPIs of the GC would be measured. Due to different measurement intervals, the main challenge is the selection of meaningful values for this constant (e.g. consumables are measured over months, while CPU usage is measured over nanoseconds). However, it is possible to compute estimations on the value of the factors during the CTI by using a simple extrapolation.

2) *Service Invocations during GC Computation Time Interval* (SICTI): this constant is defined as the total number of invocations to the service along the CTI. It will be used during the normalization.

The activity starts by converting the value of each factor into a *cost*. Then a scaling according to the CTI is performed (if needed). Processes and infrastructures generating the factors associated with the GPI could support more than one service (like data center management, control and monitoring, that could provide support to all the set of services deployed on the infrastructure). If that is the case, the value of each factor should be divided by the number of services which are supported and that will expose a GC. Finally, a cost per service invocation is computed by dividing the sum of normalized factors costs by the SICTI constant. Below, we show the equations that formalize such computation.

$$Valuation(GPI_x) = \frac{NormCost(GPI_x)}{SICTI} = \frac{\sum_{f_i \in GPI_x} NormCost(f_i) / NServ(f_i)}{SICTI}$$

in € per invocation

$$NormCost(f_i) = Cost(f_i) * \frac{CTI}{CTI(f_i)} \quad \text{in € per time unit}$$

A sample valuation of *Consumables Index* is as follows. The cost of each consumable factor is multiplied by the number of units consumed for the factor, so returning a global cost along the measurement period of each factor:

$$NormCost(Paper) = (6*8)*\frac{1}{3} = 16 \text{ € per month}$$

$$NormCost(Toner) = (2*60)*\frac{1}{3} = 40 \text{ € per month}$$

$$NormCost(Other) = 300*\frac{1}{12} = 25 \text{ € per month}$$

$$Valuation(CI) = \frac{NormCost(CI)}{SICTI} = \frac{\sum_{f_i \in \{paper, toner, other\}} NormCost(f_i) / NServ(f_i)}{SICTI} = \frac{(16+40+25)/1}{1000} = 0.0081$$

€ per inv. First, the normalized cost per factor is computed, taking into account: 1) the total cost of the factor along its measurement interval, and 2) the relationship between the measurement interval and the CTI (here 1 month). Then, the valuation of the GPI is computed, by dividing the summation of those costs by the number of services supported by the underlying processes associated to each factor (in this case 1 for all the factors), and by the SIDTI. As an output of this activity, a complete, yet unsigned, version of the GC can be generated by the service provider.

The whole process of GC creation and publication is depicted as a BPMN diagram in Fig. 3.

B. Publication Step

The activities in this step aim at making a GC public and available for service discovery engines, enabling its use by service consumers. The activities of this step are as follows:

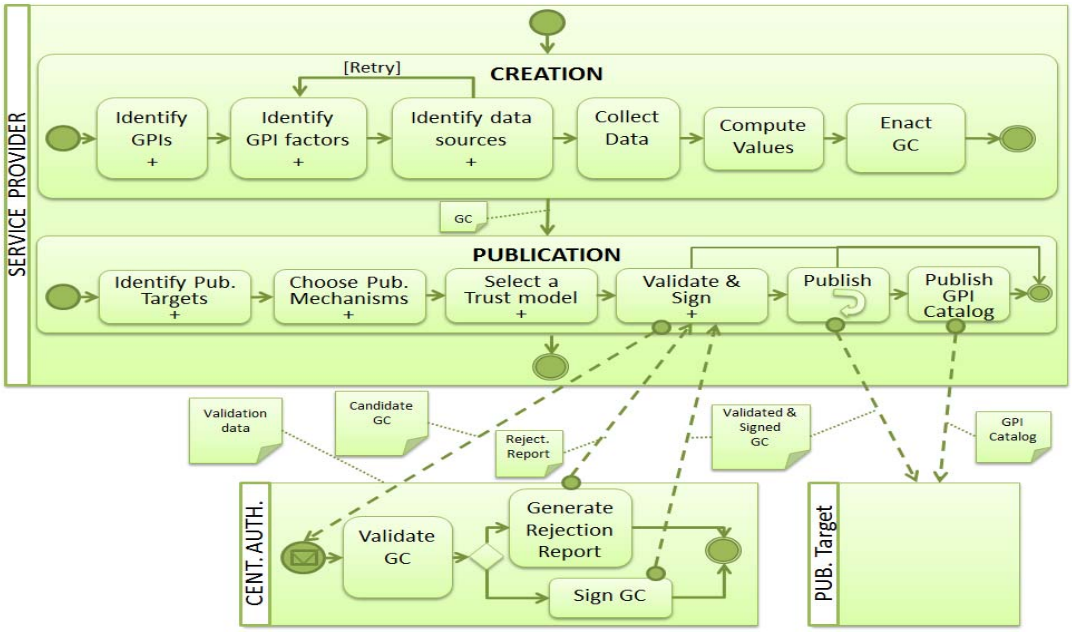

Figure 3. BPMN diagram of the GC creation and publication processes.

B1 Identify publication targets. Platforms are identified for GC publication, such as: a) *Service Registries*: e.g. UDDI and ebXML compliant platforms, and middleware platforms. b) *Web Portals / Application servers*: the GC can be published either as an isolated document or as a policy included in the service WSDL contract. c) *Middleware platforms*, such as enterprise service buses (ESBs) or SOA governance platforms, (e.g. WSO2 Governance Repository [14] or Mule Galaxy), or Service Level Agreements (SLA) creation platforms (e.g. FAST [17]). In all these platforms, the GC is published as a guarantee term of the agreement template for the service (our future work is on GC and SLA creation languages such as WS-Agreement).

B2 Choose publication mechanism for each publication target and generate the corresponding artefact based on the GC. We envision four publication mechanisms:

- As a policy attached directly to the service interface specification based on the WS-Policy serialization of GCs).
- As a guarantee term of a WS-Agreement template, i.e. an offer for the establishment of an agreement with potential user or as a clause of an actual agreement. This publication mechanism is based on the WS-Policy serialization of GCs.
- As an independent document that references the annotated service.
- As an independent GPI catalog.

B3 Selection of trust model for the published GC. During publication, the need arises to establish the trust model for the GC. In fact, the provider might not want to make some internal properties of the GPIs fully analyzable (e.g., by other providers in the same business area), or might simply want to restrict the GC analysis to companies/organizations belonging to his same virtual organization. There are basically two alternative trust models: 1) *Centralized Trust Model*, through Certification Authorities which ensure the fairness of certificates. 2) *Distributed Trust Model*, where any service provider is responsible for the authenticity, correctness, validity, integrity, etc., of the issued GCs.

B4 Publish the GC in the corresponding platforms. The component is uploaded and deployed into to the publication platforms selected in ***B1***. Details on how the GC is published could depend on the specific platforms used as targets.

C. Use Step and Disposal Step

Energy Consumption Analysis scenario**:** *Service Providers* have access to the details and data used for GC creation, namely details about GPIs, their computation and their specific data. Thus, providers can perform an ad-hoc analysis either from a global perspective or in more detail, by inspecting the energy factors in each GPI. In [18], we have considered Kiviat diagrams as representations of a simultaneous evaluation of the global costs.

Service Selection scenario**:** *Potential Service Consumers* can use the GC for service selection by comparing the valuation of the GCs of the candidate services. Costs always relate to an acceptance *range* from the customer (an absolute category of service costs for all application domains is not likely to be created). Moreover, even for a given category of services, e.g., scientific computation services or B2B services, costs cannot be evaluated for the single service but rather by comparing services having the same functionality. In order to select the most suitable service, the customer needs some detailed analysis of the causes of a cost. Such analysis can be performed for clusters or for single GPIs, depending on the *provider/customer relationship* and on market considerations, as described in [18]. The *Environmental Impact Factor* metric can be computed as the ratio between the global cost per invocation provided as global valuation on the GC and the price per invocation of the service. Considering the same price, the smaller the *Energy Impact Factor* the greener the service. Thus, potential service users can inspect this factor or the global GPI valuation to select a concrete service from the pool of services matching their price range. A WS-Agreement template can be used to provide an offer with different service profiles, defining possible agreement alternatives for service consumers. The agreement must be obtained as a balance between GCs and QoS and other non functional properties, such as the *cost per invocation* and the *response time*.

The *disposal* of a GC can be automatic (due to expiration) or forced by a request by the GC issuer, trust authority or service provider. Publication targets should withdraw the document from their platforms. In case of a forced disposal, two mechanisms can be used to inform users: i) a *notification*, where users must register on the publication authority and will be notified on forced disposal, or ii) *periodical certificate validity check* by users.

IV. Concluding Remarks

The paper has outlined a methodology to develop Green Certificates for services. Assuming that in an energy-aware context the infrastructure is developed with Green IT criteria, the activities of the methodology should be provided with automated support. Our further work considers modelling the GCs for data centers within their business processes, IT infrastructure and facilities.

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