Chapter 1
Green Specifications: A Concrete Example

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ABSTRACT

Green specifications provide a foundation for reducing the environmental impact of computing applications and improving the consumption behavior of users by providing a clear and precise specification of the environmental impact of specific services. They can either be used to specify the actual behavior and environmental impact of existing services or to define the requirements that a to-be-built service must fulfill. Green specifications describe the properties of a service from distinct viewpoints such as a structural viewpoint which describes the data types and external components that the service uses, a functional viewpoint which describes the effects of the service’s operations using pre- and post-conditions and a behavioral viewpoint which describes the externally visible states and transitions exhibited by the service. These are augmented with non-functional information describing the environmental properties of, or constraints on, the service. In this chapter we provide an introduction to green specifications and give a concrete example of their use to specify a Video on Demand (VoD) service.

INTRODUCTION

With the growing impact of computing on global warming, it is imperative that the environmental cost of IT services be reduced and that the consumption behavior of users be moderated. Green specifications (Atkinson & Schulze, 2013; Atkinson, Schulze & Klingert, 2014) provide the foundation for these improvements by providing clear and widely-understandable descriptions of the environmental cost of computing services in relation to what they do. They can either be used to describe the as-is properties of an existing service, or the required properties of a yet-to-be-built service. Only when both of these elements are unified (i.e. provided functionality and environmental impact) is it possible for service providers to arrive at optimal tradeoffs and for users to make the most informed consumption choice.

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The goal of this chapter is to provide a concrete example of green specifications applied to the specification of a realistic service, and to show how they can be used to reduce the impact of consumption of the service on the environment. The chosen example, a Video on Demand (VoD) service is a highly relevant one because a recent study by Sandvine stated that the two video streaming services Netflix and YouTube account for about 50% of all North American downstream traffic. In this chapter we therefore use green specifications to describe the required properties of an exemplary, yet-to-be-built VoD system which we call SoftFlix. Although exemplary, we have strived to make the functionality and environmental costs of the service as realistic as possible.

The concept of green specifications is a general one, and in principle any existing specification technique can be enhanced to make it “green”. However, to have maximum impact green specifications need to be understandable by the largest possible range of stakeholders in IT services, not just the service providers and system implementers. The green specification approach we apply in this chapter is therefore based on a simple yet comprehensive specification technique specifically developed to support widely-understandable specifications – the KobrA method (Atkinson, Bayer & Muthig, 2000). This makes extensive use of graphical UML diagrams and tables to describe the required properties of services from various different viewpoints.

In the next section we provide the necessary background needed to understand the green specifications described in this chapter. In particular we describe the relevant features of the KobrA development method, the concept of GreenSLAs, which provide a stepping stone to the notion of green specifications, and other existing optimization techniques which are used today to improve the efficiency of IT service. In section 3 that follows, we then introduce the SoftFlix VoD example and show how it can be specified using the standard KobrA approach. Section 4 continues by showing how the standard KobrA models from section 3 can be enhanced into green specifications by adding appropriate environmental impact constrains. In section 5 we then present some scenarios in which the information in the green specifications is used to enhance the eco-efficiency of the SoftFlix VoD service. In section 6 and 7 we provide an outlook on future work and conclude with some closing remarks.

**BACKGROUND**

In the past decade many optimization methods have been developed and applied to reduce the energy consumption and environmental impact of computing services. Green specifications make it possible to maximize the effect of some of them. In the following we will therefore provide the necessary background to understand why certain measures of green specifications lead to a reduction of the environmental impact. Furthermore, we will describe the KobrA approach in short, which is used in our example to specify the SoftFlix VoD service.

**Existing Optimization Techniques**

Recently developed optimization techniques operate at different levels of abstraction. The first, and most straightforward approach is to optimize the infrastructure. In data centers this includes the optimization of ESFs (Energy Storage Facilities) and HVAC (heating, ventilation, and air conditioning) systems as well as the actual servers. Especially since the invention of the PUE (power usage effectiveness) metric, the focus has narrowed towards the reduction of the energy consumption of the first. Free Air Cooling and