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DaaS: Cloud-based mobile Web service discovery

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ABSTRACT

The proliferation of smartphones and the recent advancement in ubiquitous wireless access have made mobile Web services more possible than ever before. However, finding relevant Web services that can match requests and fit user context remains a major concern. The challenges facing Web service discovery are further magnified by the stringent constraints of mobile devices and the inherit complexity of wireless heterogeneous networks. Cloud computing, with its flexible design and theoretically unlimited computing resources, is a viable approach to bootstrapping Web service discovery. The cloud can build bridges between mobile devices, as a convenient ubiquitous interface, and a backbone infrastructure with abundant computing resources. This paper introduces "Discovery as a service (Daas)", a novel cloud-based discovery framework that addresses the core components of mobile Web service discovery. The DaaS framework lays the foundation of efficient mobile Web service discovery that takes into consideration user preferences and context. The experimental validation and performance evaluation demonstrate that DaaS can effectively rank relevant services according to the various user context and preferences, in addition to enhancing the precision of the discovered services. The prototype also shows that Web service clustering for discovery significantly improves the overall response time, while the cloud maintains scalability according to prespecified performance criteria.

1. Introduction

The Web services approach is a key enabler of seamless integration between heterogeneous applications and software systems. Web services also can be consumed by users on the fly, given that a user-friendly interface is available that enables users to efficiently communicate with Web services. User-facing Web services are on the rise due to the proliferation of mobile devices and the advancements in ubiquitous wireless communications. RESTful Web services are capable of communicating with both applications and users via dispatching the appropriate service response to the type of service request. For example, if the request is sent by an application, an XML or JSON-formatted response is dispatched to the application, where a response with HTML format is sent to requests by Web browsers (i.e. users).

The successful implementation of Web services starts with finding relevant services that best accomplish a particular objective and are appropriate for the current context [1]. Thus, efficient discovery mechanisms for finding, ranking, and selecting the appropriate Web services are crucial to the success of adopting the Web services approach. However, due to the lack of such robust discovery techniques that understand the user preferences and context, Web services have failed to match the Web's growth.

Mobile environments present even more unique challenges for service discovery due to the intrinsic limitations of wireless network technologies and the limited resources of mobile devices, despite the advanced features and capabilities

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of the new generations of smartphones and high-end mobile devices (e.g. laptops and tablets). Researchers over the past few years have focused on optimizing specific aspects of current Web service discovery approaches in isolation [2,1,3] or overcoming individual limitations (such as intermittent connectivity) [4,5] to fit the inherent constraints and dynamic context of mobile domains. However, the lack of a comprehensive understanding of both user context, and the various constraints of mobile environments, renders most of these approaches incapable of efficient and reliable discovery in mobile scenarios.

From another perspective, Web service discovery is commonly recognized as a resource-intensive process [6], which contradicts the resource limitations of mobile devices. For example, semantic service discovery approaches perform matching at the semantic level, which better understands the semantic of Web service functionalities and non-functional parameters. Therefore, semantic approaches go beyond the syntax level and offer better discovery results by successfully retrieving all relevant services [7–9]. However, semantic approaches add significantly to the resource requirements. As such, cloud computing is candidate to bridge the gap between resource-constrained environment and resource-intensive Web service discovery. It opens up new opportunities for mobile devices to efficiently perform service discovery, while substantially reducing their resource consumption. Cloud computing not only bootstraps the performance of service discovery in mobile environments, but also removes development constraints by expanding the horizon with more options to apply sophisticated techniques that might potentially result in better service discovery.

While significant research has focused on service discovery protocols to address constraints stemming from mobile environments, they mostly lack the capacity to holistically address the different limitations and user needs. This paper introduces DaaS (i.e. Discovery as a service), a holistic discovery framework that addresses various aspects of efficient context-aware mobile Web service discovery.

The contributions of this paper are summarized as follows:

- We provide a comprehensive requirements analysis for mobile Web service discovery in resource-constrained environments.
- We introduce the concept of "Discovery as a service (DaaS)", i.e. Web service discovery as a cloud-based service. We demonstrate the viability of our framework with a use case and a proof-of a-concept implementation.
- We integrate user preferences and context into service discovery to find services that best fit the user needs.
- We present analytical models to calculate the relevance of candidate services to a particular aggregated context.

The remainder of this paper is organized as follows. Section 2 presents a motivating scenario. Section 3 outlines related research. Section 4 discusses the current discovery approaches, points out the limitations, determines the essential requirements for efficient discovery in mobile environments, and identifies how the cloud can bootstrap service discovery. Section 5 describes the proposed framework and relevant research efforts that may be potentially applied for each component. The framework functionality is validated in Section 6 and a performance evaluation is presented in Section 7. Finally, Section 8 draws the concluding remarks of the paper.

2. Motivating scenario

Adam is visiting France on a vacation. Adam's first language is English and he has a basic knowledge of French but cannot effectively communicate in French. While traveling, Adam prefers to pay using his credit cards to reduce the amount of foreign currency he has to carry. He follows a strict diet that limits his options. Adam spends most of his day outside visiting tourist attractions. He uses his 4G-connected smartphone for guidance, itinerary optimization, and searching for services such as attraction recommendations, restaurants, and currency exchange. Although Adam is connected to the Internet through his roaming plan, he sets his smartphone to connect to free WiFi spots whenever applicable to reduce the cost and take advantage of the higher bandwidth WiFi offers.

During lunch time, Adam searches for restaurants in his vicinity. Adam wishes to find a restaurant that provides food that meets his dietary regulations and offers flexible payment options, English language communication, and complementary WiFi access. Adam typically plans the remainder of his day while waiting for his meal to be served by exploring services that offer tourist recommendations that include photo snapshots, video trailers, and visitor feedback.

In such a scenario, Adam faces several challenges finding services that know about his context and can accommodate his preferences. For example, searching for a restaurant with traditional Web service discovery approaches may recommend a list that includes restaurants that are not within walking distance and perhaps others that do not offer service in English or flexible payment options. Additionally, such approaches provide no priorities to services that accommodate Adam's preferences such as dietary constraints. For example, he may prefer to satisfy his dietary constraints over proximity. Existing service discovery approaches lack the ability to support such a level of convenience. DaaS offers suitable service discovery in such a scenario through integrating the user context and preferences with the discovery process.

3. Related work

Service discovery spans multiple levels ranging from infrastructure service discovery (e.g. physical resources such as printers) to application-level service discovery, where end-users search for network functions that satisfy their objectives. The context is an inter-layer concept integrated in all discovery levels [1]. The framework presented in this paper is concerned with service discovery at the application level.

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