Chapter 91
The Ubiquitous Semantic Web:
Promises, Progress and Challenges

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ABSTRACT

The Semantic Web represents an evolution of the World Wide Web towards one of entities and their relationships, rather than pages and links. Such a progression makes it possible to represent, integrate, query and reason about structured online data. Recent years have witnessed tremendous growth of mobile computing, represented by the widespread adoption of smart phones and tablets. The versatility of such smart devices and the capabilities of semantic technologies form a great foundation for a ubiquitous Semantic Web that will contribute to further realising the true potential of both disciplines. In this paper, the authors argue for values provided by the ubiquitous Semantic Web using a mobile service discovery scenario. They also provide a brief overview of state-of-the-art research in this emerging area. Finally, the authors conclude with a summary of challenges and important research problems.

1. INTRODUCTION

The Semantic Web (Berners-Lee, Hendler, & Lassila, 2001) was envisioned more than a decade ago. In this vision, the Web of pages and links is replaced with a Web of data, represented by entities with semantic relationships. Such entities and relationships are described by *ontologies*, formal representation of domain knowledge. Over the past years significant progress has been made in Semantic Web research, including practical and expressive ontology languages (Horrocks, Patel-Schneider, & van Harmelen, 2003; Baader, Brandt, & Lutz, 2005; Horrocks, Kutz, & Sattler, 2006; Stoilos, Stamou, & Pan., 2010; Qi, Ji, Pan, & Du, 2011), efficient ontology reasoning (Horrocks &

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Sattler, 2005; Baader, Lutz, & Suntisrivaraporn, 2006; Pan & Thomas, 2007; Ren, Pan, & Zhao, 2010; Kazakov, Krötzsch, & Simancik, 2011), scalable query answering (Stocker, Seaborne, Bernstein, Kiefer, & Reynolds, 2008; Newman, Li, & Hunter, 2008; Pan & Thomas, 2007; Fokoue, Meneguzzi, Sensoy, & Pan, 2012), and large-scale, distributed, and inter-connected data sets in Linked Data (Bizer, Heath, & Berners-Lee, 2009a, 2009b; Hogan, Pan, Polleres, & Ren, 2011; Urbani, van Harmelen, Schlobach, & Bal, 2011; Liu, Qi, Wang, & Yu, 2011; Fokoue et al., 2012; Tachmazidis, Antoniou, Flouris, & Kotoulas, 2012; Mutharaju, 2012), to name a few. Semantic languages and technologies have also been increasingly adopted in a number of domains, especially in the biomedical domain (Wang, Gorlitsky, & Almeida, 2005; Machado, Rebholz-Schuhmann, Freitas, & Couto, 2013).

The emergence of handheld devices, such as smart phones and tablets, has arguably heralded the post-PC era. The recent years have witnessed an explosive growth of such smart devices, with the iOS and Android being two leading platforms. Collectively Android and iOS dominate the smart devices market, accounting for more than 90% of the market share (calculated by units shipped) as of Q3 2013, with Android taking 81% of the market share.[1]

Smart devices are typically equipped with a comprehensive operating system, generous computational resources, and versatile connectivity and sensing capabilities, and they have truly enabled ubiquitous and situation-aware communication. Understanding and processing the *semantics* of data is, we believe, an important addition to smart devices and therefore an area of tremendous practical value. In other words, we argue that the development of *the ubiquitous Semantic Web* can significantly improve both areas.

Semantic Web languages and technologies have been successfully applied in the area of ubiquitous computing for representing, reasoning about contexts, modelling sensor network and data integration. Semantic technologies have also been adapted on non-PC devices. However, as we will present in Section 5, there are still significant obstacles to overcome to truly create the ubiquitous Semantic Web.

The rest of the paper is organised as follows. We begin with a hypothetical scenario of mobile service discovery to motive the case for a ubiquitous Semantic Web in Section 2. A brief introduction to major Semantic Web languages is given in Section 3. Section 4 is devoted to a discussion of existing works in ubiquitous Semantic Web, focusing on two particular areas: context modelling, and ontology reasoning on mobile devices. Major research challenges and important research directions will be presented in Section 5, and finally, we conclude the paper in Section 6.

2. MOBILE SERVICE DISCOVERY: A MOTIVATING SCENARIO

In this section we present a fictional, yet realistic scenario for mobile service discovery where ontologies are used to represent contextual information, and ontology reasoning is used to perform service matching. Such a scenario advocates the value of a ubiquitous Semantic Web. For a thorough review to such ubiquitous applications, we refer readers to (Ermilov, Khalili & Auer, 2014).

A tourist, John, finds himself in a shopping centre in a foreign country. John is in possession of a smart phone. However, there is no cellular or Wi-Fi network that John can use. However there are iBeacon-like[2] services that can push notifications to compatible mobile devices.

Besides location information, each store also pushes notification of its speciality, catalogue, sales items, etc. We assume that for compatibility reasons, all the stores have agreed to use a common "vocabulary", an ontology (e.g., schema.org), for marking up such notifications. We also