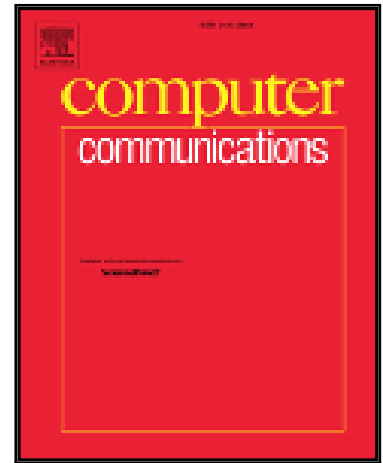


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Online Advertising: Analysis of Privacy Threats and Protection Approaches

José Estrada-Jiménez, Javier Parra-Arnau, Ana Rodríguez-Hoyos and Jordi Forné

Abstract—Online advertising, the pillar of the “free” content on the Web, has revolutionized the marketing business in recent years by creating a myriad of new opportunities for advertisers to reach potential customers. The current advertising model builds upon an intricate infrastructure composed of a variety of intermediary entities and technologies whose main aim is to deliver personalized ads. For this purpose, a wealth of user data is collected, aggregated, processed and traded behind the scenes at an unprecedented rate. Despite the enormous value of online advertising, however, the intrusiveness and ubiquity of these practices prompt serious privacy concerns. This article surveys the online advertising infrastructure and its supporting technologies, and presents a thorough overview of the underlying privacy risks and the solutions that may mitigate them. We first analyze the threats and potential privacy attackers in this scenario of online advertising. In particular, we examine the main components of the advertising infrastructure in terms of tracking capabilities, data collection, aggregation level and privacy risk, and overview the tracking and data-sharing technologies employed by these components. Then, we conduct a comprehensive survey of the most relevant privacy mechanisms, and classify and compare them on the basis of their privacy guarantees and impact on the Web.

Index Terms—online advertising, Web tracking, user profiling, privacy risks.

I. INTRODUCTION

Selecting and directing information are crucial in every aspect of our modern lives, including areas as diverse as health, leisure and research. In the past, these processes were largely manual, but due to the exponential improvements in computation and sophistication of software, they are becoming increasingly automated.

The industry of online advertising, lavishly illustrated by Google DoubleClick and real-time bidding (RTB), is an example of the ever-growing automation of these processes, and another crucial aspect of our society — to a large extent, the success of most competitive economic activities is dependent on advertising, particularly on the ability to effectively select and direct information to the right potential customers.

Undoubtedly, the advent of the Internet and the Web has created a myriad of new opportunities for advertisers to target

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Fig. 1: Word cloud of terms related to online advertising, tracking, user profiling, and privacy solutions in this scenario. We discuss all these terms in this work. The font size of each of them is proportional to the frequency of occurrence in Google search.

billions of people almost effortlessly. However, online advertising is not only ubiquitous. In the early days of the Web, ads were served directly by the publisher (i.e., the page’s owner) following a one-size-fits-all approach. But due to the ease with which Web users can be tracked across their page visits, online advertising has also become increasingly personalized. An example of the sophistication of ad personalization is RTB, which enables advertisers to direct ads to the right user and at the right time, by competing in real-time auctions for the impression of their ads [1].

Evidently, personalized advertising is the most effective, and hence the most profitable, form of advertising. According to a recent survey, those ads relying on a user’s browsing interests ensure conversion rates¹ that double those of untargeted ads [2]. On the other hand, from the publishers’ perspective, online advertising is the pillar that sustains the Internet’s “free” content and services.

Nevertheless, advertisers and publishers are not the only entities taking part in this business. In fact, there exists an entire infrastructure at the service of both of them, supported by companies like Google, Facebook and Twitter. Enabled by these and hundreds of other ad companies, targeting mechanisms take charge of selecting and directing ads to billions of users everyday, depending on a number of factors such as the page they are visiting; their browsing history; their IP address or parts of it; their operating system; the plug-ins installed and other information related to their Web browser [3], [4], [5]; and obviously the objectives and budgets of all advertisers for displaying their ads.

User information is therefore an asset fundamental to the efficient and effective delivery of advertising, which is not

¹In online marketing terminology, conversion usually means the act of converting Web site visitors into paying customers.

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