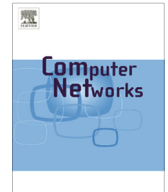




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A privacy-aware framework for targeted advertising

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ABSTRACT

Much of today's Internet ecosystem relies on online advertising for financial support. Since the effectiveness of advertising heavily depends on the relevance of the advertisements (ads) to user's interests, many online advertisers turn to targeted advertising through an ad broker, who is responsible for personalized ad delivery that caters to user's preference and interest. Most of existing targeted advertising systems need to access the users' profiles to learn their traits, which, however, has raised severe privacy concerns and make users unwilling to involve in the advertising systems. Spurred by the growing privacy concerns, this paper proposes a privacy-aware framework to promote targeted advertising. In our framework, the ad broker sits between advertisers and users for targeted advertising and provides certain amount of compensation to incentivize users to click ads that are interesting yet sensitive to them. The users determine their clicking behaviors based on their interests and potential privacy leakage, and the advertisers pay the ad broker for ad clicking. Under this framework, the optimal strategies of the advertisers, the ad broker and the users are analyzed by formulating the problem as a three-stage game, in which a unique Nash Equilibrium is achieved. In particular, we analyze the players' behaviors for the scenarios of independent advertisers and competing advertisers. Extensive simulations have been conducted and the results validate the effectiveness of the proposed framework by showing that the utilities of all entities are significantly improved compared with traditional systems.

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1. Introduction

Online advertising provides financial support for a large portion of today's Internet ecosystem, and is displayed in a variety of forms embedded in web sites, emails, videos and so on. As the effectiveness of advertising largely depends on the relevance between the delivered advertisements (ads) and users' interests, a popular paradigm for current online advertising system is targeted advertising, where advertisers hire an ad broker to deliver ads to potentially interested users by analyzing users' online profiles or

behaviors [1]. Targeted advertising is beneficial to both advertisers and users: advertisers can gain higher revenue by advertising to users with a strong potential to purchase, and the users in turn receive more pertinent and useful ads that match their preferences and interests. A recent survey [2] revealed that targeted advertising brings 2.68 times revenue per ad compared with non-targeted advertising. Due to the increased effectiveness and benefits, a number of advertisers around the world have already turned to online targeted advertising systems. Examples of such advertising systems include Google AdWords [3] that deliver customized ads based on search items, and Ink TAD [4] that pushes ads according to location information revealed in user's emails.

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Although targeted advertising benefits both advertisers and users, it has raised severe privacy concerns. A recent survey [5] of 2253 participants conducted in 2012 reported that the majority of respondents expressed disapproval of targeted advertising due to privacy disclosure. Such privacy threats come from the fact that ad brokers aggressively track users' online behaviors to obtain their preferences and interests, which can be sensitive to the users. For example, the behavior of searching for a certain kind of medicine implies that the user is likely to have certain relevant disease, whose disclosure is considered as a violation of the user's privacy. Moreover, ad brokers rarely have clear statements about how the obtained behavioral data will be used and whom the data will be shared with. Untrusted ad brokers may sell such personal information to some adversaries without the user's permission. Being aware of such privacy risks, users are reluctant to embrace the practice of targeted advertising [6], which hinders the effectiveness of online advertising systems.

To maintain the merits brought by targeted advertising, it is essential to incentivize users to participate in such systems. Existing studies [7–9] have focused on privacy preserving mechanisms to encourage users to involve in the targeted advertising systems. These mechanisms either assume another trusted entity sitting between users and ad brokers [7,8], or require users to send perturbed clicking information to hide users' true data. However, these changes made on the framework of existing targeted advertising systems provide privacy protection at the cost of the benefits of ad brokers or advertisers. The ad brokers may not be in favor of introducing an extra entity to share their ad targeting duty, which is the main source of their revenue. Similarly, the advertisers may be dissatisfied with the perturbed clicking information as perturbation undermines the accuracy of click information, which normally determines their payments [10]. Without guaranteed revenue, the advertisers and ad brokers naturally tend to maintain the adoption of traditional targeted advertising systems instead of upgrading the systems to provide privacy protection. This conflict between users and advertisers/ad brokers hinders the adoption of privacy-aware mechanisms in advertising. To promote the adoption of the privacy-aware advertising systems, the interests of all entities should be guaranteed, which, unfortunately has not yet been addressed by existing proposals.

In this paper, we propose a privacy-aware framework to boost the adoption of privacy preserving targeted advertising systems. Users, the ad broker and advertisers are assumed to be rational and selfish entities, who care only about their own interests. To ensure the interests of all entities, our framework introduces an economic compensation mechanism for privacy leakage. Such economic compensation for privacy loss has already been widely considered in the literature [11,12]. Besides, many companies, including Bynamite, Yahoo, and Google, are also engaging in the purchase of users' private information in exchange for monetary or non-monetary compensation [13,14,12]. Under the proposed framework, the ad brokers compensate economically for the users' privacy leakage in order to incentivize users to click their interested ads. On the one hand, the users, with the expectation of receiving

compensation, are inclined to click ads of interests. On the other hand, as the compensation can improve click-through rate and bring the ad broker more revenue, the ad broker is willing to provide certain amount of compensation for users whose ad clicks reveal their private interests. However, to support this framework, there are still several questions that need to be answered. First and foremost, in order to compensate privacy loss, it is essential to quantify privacy information leakage in ad clicks. Second, how much compensation should be provided for each user? The more compensation provided, the more inclined users are to click ads; while the ad broker pays more for the users' privacy loss. Moreover, how should advertisers pay the ad broker for the ad clicks they benefit from? The amount of payment to the ad broker has an impact on the privacy loss compensation allocated to users, which in turn affects the click-through rates and advertisers' revenue. In this paper, we answer all these questions via game theory analysis. In particular, we propose an ad dissemination protocol to protect the users' privacy to a large extent, and formulate the interactions among all entities as a three-stage game, where each entity aims to maximize its own utility.

The main contributions of this paper are summarized as follows.

- We propose a privacy-aware framework for targeted advertising to motivate users, the ad broker, and advertisers to be engaged in the targeted advertising systems. This framework requires no modifications on existing targeted advertising systems, and takes the incentives of all parties into consideration. In our framework, the ad broker provides a certain amount of compensation for the users' privacy leakage from ad clicks in order to encourage users to click their interested ads, which in turn improves the click-through rate and brings in more revenue for the ad broker and advertisers.
- We model the framework as a three-stage Stackelberg game, in which all entities are considered to be selfish, targeting at maximizing their own utilities by selecting optimal strategies. We analyze the cooperation and competition relationship among users, the ad broker, and advertisers, and derive the Nash Equilibrium.
- We further analyze the competition among advertisers who share the whole market. We model the market sharing scenario as a non-cooperative game and prove the existence of the Nash Equilibrium.
- We conduct numerical simulations to evaluate the proposed framework. The results verify that the utilities of all entities are notably enhanced, which provides strong motivation for the ad broker and advertisers to implement the compensation policy and users to embrace the targeted advertising.

The rest of the paper is organized as follows. Section 2 describes the system model. Section 3 introduces the compensation framework. In Section 4, we model the framework as a three-stage game and analyze the optimal strategies of advertisers, the ad broker and users. We further discuss the competition among advertisers for market sharing. Numerical results are shown in Section 5 and

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