Information Disclosure in Real-Time Bidding Advertising Markets

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Abstract*—Real-time bidding (RTB) advertising is a fast-growing business model in online display advertising markets. Unlike the guaranteed display advertising, it utilizes programmatic instantaneous auction to price and sell ad inventory on a per-impression basis. RTB enbales advertisers to target audiences at demographic, psychographic or behavioral levels across a wide range of websites. In RTB markets, information about target audiences is usually disclosed to advertisers, while information about publishers (e.g. website ranking, advertising page) are typically not avaliable for advertisers, especially in real-time setting. This leads to a serious information asymmetry problem in RTB markets, which has significant influence on both advertisers' bidding strategies and publishers' revenues. In this paper, we study the information disclosure strategies of publishers in case when the disclosure may incur an extra cost. We address this information asymmetry problem by first formulating the RTB auction as an second-price sealed-bid game, then discussing equilibrium information disclosure strategies for publishers and also investigating advertisers' bidding strategies in the three information disclosure cases: all disclosed, non-disclosed, and partially disclosed. We find that non-disclosed and partially disclosed strategies may lead to an adverse selection effect, and high-quality publishers will be forced to quit the RTB markets .

***Keywords*—real-time bidding; information disclosure; asymmetric information; adverse selection**

I. INTRODUCTION

Real-time bidding (RTB) is a modern method of online display advertising based on audience targeting. Since its birth in 2005, RTB has witnessed a rapid development in recent years. For instance, Google reports show that the average growth rate of the US RTB markets in the recent five years reaches 70.5%, and more than 50% display ad inventory will be sold via RTB in 2015. In China, RTB ad budgets have increased by 300% to 83 billions in 2013, according to IDC (*Internet Data Center*). RTB is expected to be a major business model of online display advertising in the future. Unlike traditional online advertising with the aim of buying media or ad slots, RTB focuses on buying target audiences, and thus can help advertisers get more effective traffics and better marketing performance. RTB allows advertisers to bid for impressions according to promotion purpose, targeting audience, budgets and so on. Driven by big data, RTB has the potential of achieving precision marketing.

In RTB markets, an ad slot is sold through the following process: first, when an audience accesses a web page, an impression is triggered, and SSP(Supply-side platform) will send the information about the impression to Ad Exchange; then, Ad Exchange transmit this information to DSP (Demand-side platform); each DSP firstly gets related information about the audience behind the impression through DMP (Data management platform), then chooses proper advertisers to bid for the impression, and feeds the winning bid back to Ad Exchange; According to specific mechanisms, Ad Exchange chooses the highest-bidding advertiser as the winner, who will get the ad impression; finally, SSP gets information about the winning advertiser and displays her ad in the corresponding webpage in case when the price paid by the highest bidder is no less than the publisher's reserve price; otherwise, even the advertiser wins the auction, she will lose the ad display opportunity.

During the RTB ad auctions, information is the most important component since it is not only the main reference for advertisers to evaluate the impression, but also the key support for the publisher to rely on for good bidding price. Although RTB allows advertisers to buy ads based on audience characteristics, they still care about which publishers their ads are displayed on. Here, advertisers differentiate publishers according to their qualities, which is mainly defined by the website ranking and advertising page. An impression showing in the higher-quality web page will be more valuable for advertisers than that in the lower-quality web page. This can be easily justified by the fact that high-quality web pages typically can attract more advertisers and get higher price of the ad slots. Thus, while RTB offers an unprecedented opportunity to target specific audiences, advertisers do care a lot about having their brands showing up in premium environments. However, in RTB market, the demand side and the supply side may get asymmetric information about the pub-

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lisher's quality because of the information hiding or unaffordably high information disclosure cost. For an advertiser, information asymmetry makes her deviate from the true valuations of the impression thus the biddings. For a publisher, if she knows more about the impression than advertisers, there are two cases dependent on the quality of them. If the publisher's quality is low, she is willing to keep the information undisclosed to encourage the bidding competitions for high profits; and if the quality is high, she will suffer unnecessary loss because of the advertisers' over-low expectation of the quality. Thus, information disclosure is significant for both publishers and advertisers. Only if the publisher's quality is disclosed to advertisers, then will the bids match real value of the impression. Asymmetric information will change the revenue-sharing scheme in RTB market, potentially resulting in adverse selection. As a result, high-quality publishers will quit the RTB markets.

In RTB practice, one potential approach for publishers to disclose their quality information is to build private Ad Exchanges. However, the cost of such private Ad Exchanges is unaffordably high, especially for small publishers. In order to tackle this problem, we investigate publishers' information disclosure strategies in RTB markets, aiming at solving the adverse selection problem caused by information asymmetry. We will find equilibrium information disclosure strategies for publishers in a RTB impression auction game. Also, we will discuss advertisers' bidding strategies under different settings, e.g., all disclosed, non-disclosed, and partially disclosed.

The contribution of our paper can be summarized as follows. This paper represents the first attempt to address the asymmetric information problem of publishers' quality in RTB markets. We consider publishers' reserve price via the opportunity cost of ad impressions, and also take information disclosure cost into consideration to study the publishers' information disclosure strategy. We also investigate advertisers' bidding strategies. We find that non-disclosed and partially disclosed strategies may lead to an adverse selection effect, and then high-quality publishers will be forced to quit the RTB markets

The rest of this paper is organized as follows. Section II reviews the existing literatures about RTB advertising and information disclosure. Section III studies the problem of information disclosure in a RTB impression auction game. Section IV discusses the equilibria, and Section V concludes this work.

II. LITERATURE REVIEW

In RTB markets, strategy optimization is a crucial problem that attracts intensive attention from publishers and advertisers. Generally speaking, an advertiser's bid is affected by her valuation of an impression, her budget and the competitors' bids. Oppositely, the bid of an impression is also a signal of its value [1], which is crucial for publishers' yield optimization. For RTB, a publisher implementing the contract through bidding should offer advertisers a range of prices, which requires randomized bidding [1]. Bid optimization is thus a standard problem of the RTB advertisers for targeting more ad display and also the DSP for improving production system [2]. Bid should be based on their valuations of the impression, which is greatly affected by information disclosure. Advertisers want to select high quality impressions, and maybe adjust the bid price based on the prior performance distribution [3], and if there is enough information for her bidding decision, he prefers to bid higher for the high-quality impressions. Through the empirical study, [4] found that current bidding strategy is still far from optimality, indicating the needs for consideration of temporal behaviours, the frequency and recency of ad displays. In [5], researchers tried to predict the bid distribution for any advertising campaign in RTB market in real time, since there is no accurate prior information for advertisers to rely on. All the above efforts on bidding strategies are closely related to the information disclosure.

Information is the base for advertisers to valuate impressions, and also the support for publishers to win reasonable bids. Information is said to be asymmetric if the precision of the signals observed varies across the participants [6]. An extreme case is an auction in which one agent has (exact) private information about the value of the object, and others have access only to (noisy) public information [7], which is just the situation as in RTB advertising market. Publishers have private information about each impression, while advertisers are only exposed to some noisy information. There is much research about the influence of information asymmetry on the participants' decisions, strategies or revenues. It has proved that in online auctions of used goods, disclosure costs impact both the level of disclosure and the prices obtained by sellers, and consequently incentives for seller participation [8].

Information disclosure is seldom mentioned in current research about RTB advertising. In RTB literatures, they usually consider the environment with a single publisher or homogenous publishers. However, in market practice, publishers are different in quality, which means that even with the same audience; the impressions on different publishers' websites will have different valuations for advertisers. Accordingly, advertisers will bid differently for them. Therefore, it is necessary to take the publisher's quality into consideration. If all information is public and symmetric to every participant, high-quality publishers can definitely win higher bid than that of low-quality publishers. However, in public Ad Exchange, it is hard for publishers to disclose their own qualities. Also, it costs a lot for publishers to disclose their qualities through building private Ad Exchange, but may bring in considerable incomes. In the next section, we will study the information disclosure in an impression auction, and try to find the conditions on which the publishers are willing to disclose their own qualities. Also, we will analyze some equilibrium properties, and discuss the bidding strategies of advertisers in different information disclosure cases.

III. INFORMATION DISCLOSURE IN AN IMPRESSION AUCTION GAME

In this section, we will study the information disclosure problem in the RTB market. Firstly, it is necessary to introduce information asymmetry and costly disclosure. We assume that the publisher can privately observe an ex-post verifiable signal of the value of each impression, which is impres-

sion "quality", but advertisers cannot. In RTB markets, characteristics of the audience behind the impression should be disclosed for the purpose of precision marketing, thus the information asymmetry is only concerned to the publisher's quality. It is costly for the publisher to publicly disclose her quality. These disclosures are thought to be truthful, since they can be verified ex-post and information distortion will result in punitive charges. The advertiser's valuations of the impression are influenced greatly by the information disclosed, which represents that the auction is with interdependent values.

Real time bidding is a second-price sealed-bid auction with the private reserve price and an unobserved number of advertisers. Publishers are allowed to pre-set reserve price for each impression, since they can also sell impressions through guaranteed online contracts. In RTB, we assume that the number of advertisers is random, and both publishers and advertisers/DSPs know its distribution. Furthermore, we consider the RTB auction as a series of separated game sessions, in order to simplify our deduction of how the information disclosure costs influence market performance.

Also, the publisher usually has alternative options to sell the impressions, e.g. through guaranteed offline contracts. This indicates that she has opportunity cost to sell the impressions through RTB. Opportunity cost (i.e., alternative option) is an important reference for the publisher to set reserve price.

Considering that a publisher P has an impression to sell, and the quality of the impression is captured in a private signal Q. The signal should be defined as a quality index, including the publisher's quality, the specific webpage and so on. As aforementioned, The publisher also has an alternative option to sell the impression through guaranteed contracts, which is set as private V_P. Then the publisher's type is (Q,V_P), and the joint distribution is F_{Q,V_P} with bounded support. It can be easily proved that better quality of the impression results in better alternative option. Reserve price r is set to make sure the impression is sold at a proper price. The transaction price b is the second highest bid and the maximal r.

When the publisher decides to sell the impression through RTB market, n advertisers will bid for it in a second-price sealed-bid auction. n is random and unknown to all players, but its distribution f_n is public. Each advertiser has a private information X_i about the impression, which is independently subject to a distribution g_X, and dependent on Q. We assume that advertisers are risk-neutral. If the advertiser i wins the auction and the second highest bid is no less than r, she has a quasi-linear payoff as $v(Q,x_i)-b$; otherwise, the payoff is zero. The valuation $v(Q,x_i)$ is strictly increasing and continuously differentiable in both vectors. If information of the impression is totally disclosed, valuation is conditional on Q and differs only in the advertiser's personal interpretation x_i. However, information disclosure is costly; the publisher must pay c to disclose signal Q and a fixed cost F to sell the impression through RTB. Thus, the publisher's payoff function can be formulated as:

$$\pi_P=\begin{cases} b-F-cd, & sells\ \ through\ \ RTB \\ V_P-F-cd, & through\ \ RTB, does\ \ not\ \ sell \\ V_P, & sells\ \ through\ \ guaranteed\ \ contract \end{cases}$$

where d is a binary variable, and if the publisher disclose Q, we have $d=1$.

When the publisher sells the impression in RTB market, he should simultaneously decide whether to disclose the impression/publisher quality. Reserve price also would be set in advance to ensure the revenues. Each advertiser will then observe the disclosed information q, and bid according to her strategies $s(q,x_i)$. Actually, reserve price r is kept as secret, and thus it cannot influence the advertiser's strategy. Under this situation, the revenue for the publisher to disclose her quality can be defined as $\pi'_P(q,r,V_P)$. Then, we define the new payoff function as:

$$\pi'_P(q,r,V_P)=\begin{cases} s(q,x_2)-V_P-cd, & s(q,x_2)\geq r \\ r-V_P-cd, & s(q,x_1)>r>s(q,x_2) \\ -cd, & otherwise \end{cases}$$

where $s(q,x_1), s(q,x_2)$ are the highest and second-highest bids. c is not a constant, and it is related to the extent of information disclosure. Thus, we have $c=c(q)$, and c increases with q. Since V_P is certain and known for the publisher, it is rational for us to view it as the cost of the impression in the payoff function. For the publisher, only if the expected payoff surpasses the fixed threshold cost F, she would like to sell the impression through RTB. Thus, we have:

$$E[\pi'_P(q,r,V_P)]>F$$

If the disclosure cost is finite, with regard to each disclosure q, there must exist an infimum $V_P^*(q)$ of the alternative option for the publisher to choose selling impressions in RTB market. It has proved that costless disclosure leads to full disclosure, while infinitely costly disclosure results in adverse selection [9, 10].

IV. EQUILIBRIUM ANALYSIS

The impression auction can be formulated as a symmetric game in RTB markets. With restricted costs, the equilibrium disclosure can be described by a threshold q^* satisfying the condition $q\geq q^*$ with $d=1$. For the publisher, the optimal reserve price $r^*(q,V_P)$ increases in V_P, and she tries

to sell the impression in RTB markets only if her payoff is no less than that of the guaranteed contracts, which is $V_P \le \pi'_P(q,r,V_p)$. When the game reaches an equilibrium, if arguments of $v(Q,x_i)$ can be separable, q^* will increase in V_P and $r^*(q,V_P)$ will increase in q. If the alternative option leads to better revenues, the publisher will be confident about her quality, and prefers to disclose more information about the impression quality to win higher bids. Also, if the publisher discloses more information, it is rational for advertisers to believe that she is confident about her impression quality, which will also result in higher reserve price.

When in the equilibrium state, the advertisers' bids must be based on the information disclosure, thus, we have:

$$s(\hat{q},x_i)=\begin{cases} v(Q,x_i), q=Q \\ E[v(Q,x_i)\big|Q<q^*], q=\phi \\ E[v(q,x_i)], q\neq\phi, q\neq Q \end{cases}$$

As follows, we will discuss three cases of information disclosure. Firstly, if the publisher discloses all the information about the impression, that is $q=Q$, each advertiser will formulate a private valuation of the impression, and in the RTB market, it is a weakly dominated to bid on the valuation. In the case that the publisher does not disclose any information, the advertisers valuate and bid according to the expectation of the impression quality. It has great possibility that non-disclosed publisher will be considered with low quality, thus, the strategy should be conditioned on $Q<q^*$. Low-quality expectation will lead to adverse selection, since advertisers are not willing to bid high for the impression, and high-quality publisher wouldn't like to sell the impression on an undervalued price, then the impression is probably a low-quality one finally. Under this situation, the advertisers have another condition that $V_P \le V_P^*(\phi)$ for their biddings, where $V_P^*(\phi)$ is the upper bond of the guaranteed contracts price for the impression of non-disclosed publisher. Besides of these two extreme cases, there is another more sophisticated one, where the publisher discloses partial information, which is not enough for advertisers to confirm the impression quality, but provides good evidence for advertisers to predict it. Under this situation, the impression may be high-quality or low-quality with a certain probability, respectively. Then, advertisers will formulate an expectation of it and bid according to the expected valuation. Here, we have:

$$E[v(q,x_i)]=\lambda_i v(Q,x_i)+(1-\lambda_i)E[v(Q,x_i)\big|Q<q^*]$$

and λ_i is the probability that the advertiser i judges the impression showing in a high-quality publisher. Note that each advertiser has an individual λ.

Although information disclosure can help the publisher win good bids, she is still restricted by the disclosure cost. Increasing disclosure cost will improve the selling cost of the impression, and also the risk that can not be sold through RTB, because it will weaken the incentives for the advertisers to bid. On the other hand, non-disclosure and partial disclosure has less disclosure cost, but increase the risk that the advertisers pay higher than its real valuation, which will also restrict the advertisers to participate in impression auction. Thus, given the disclosure cost, the publisher should decide to what extent the information should be disclosed.

V. CONCLUSIONS

Information asymmetry between the publishers and advertisers has significant influence on the bids, payoffs, and even market structures of RTB markets. In order to solve the information asymmetry problem, we study the publishers' information disclosure strategies in RTB markets. We take the publisher's quality into consideration, and view it as a vital component for advertisers to evaluate the impressions. We study the costly information disclosure in impression auction game, and then analyze some important equilibrium properties of the game. We discuss three cases of information disclosure: all disclosed, non-disclosed, partially-disclosed, and investigate the bidding strategy for advertisers under these cases.

We believe that building a private Ad Exchange is a good alternative way of information disclosure for publishers in RTB market practice, with the aim to encourage their advertisers to increase ad budgets for a premium segment of inventory. These private Ad Exchanges can serve as evidence that information disclosure is profitable for publishers, since otherwise they have no incentives to invest on private exchanges for disclosing information. In our future work, we will study the bidding strategy under different information disclosure cases, and try to do some empirical study of information disclosure in RTB markets.

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