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Application Research Based on GSP Auction Mechanism

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ABSTRACT
In order to better choose a suitable auction method and achieve the best overall return, this paper compares and analyses Generalized-Second position (GSP) from the three aspects of experimental simulation results, actual profitability and real market distribution based on the advantages and disadvantages of the two different auction mechanisms of GSP and Vickrey–Clarke–Groves (VCG). The two auction mechanisms of VCG are combined with real data for comparative analysis. Research shows that in actual profitability and reality, the "profitability" of GSP is better than that of VCG, and the GSP auction environment is more suitable for the current network.

Keywords*: GSP, VCG, Experimental simulation results, Actual profitability, Real market distribution*

1. INTRODUCTION

1.1. Research Background and Motivation

Internet auction refers to the auction on the Internet, as a way of auction across time and space, provides a new idea and method for the auction itself, so compared with the traditional British auction, Dutch auction, more popular with the masses. The search engine "keyword auction" in the Internet auction is also one of the profit methods of Internet companies, especially search engine companies, such as Google and Yahoo. Search engine auction means that when users search on search websites, corresponding online advertisements will be placed on the top of the content they want to search. When users search keywords, they can see advertisements so that advertisers' advertisements can be spread. However, the network auction involves a wide range of advertising on different positions and keywords, making the same advertising advertisers have different advertising effects. There are many types and mechanisms of online auction, and the mechanisms and algorithms behind them are also different. The GSP algorithm studied in this paper is a unique auction method tailored for the unique environment of the online advertising market. GSP is similar to Second Price Sealed Bid & VCG. For example, if a user searches for the keyword "Google AD" on a search engine, the company can auction the keyword. Advertisers have to say how much they are willing to pay for the placement. The highest bid will appear at the top, the second bid will appear at the second spot, and the winner (the first AD) will pay the second highest bid, and so on, the i advertiser will pay the i +1 bid. When a user searches Google AD, the user receives the search results and an Internet advertisement link [1]. Google's total revenue in 2005 was $6. 14 billion. Over 98 percent of its revenue came from GSP auctions. Yahoo!'s total revenue in 2005 was $5. 26 billion. A large share of Yahoo!'s revenue is derived from sales via GSP auctions. It is believed that over half of Yahoo!'s revenue is derived from sales via GSP auctions. "As of May 2006, the combined market capitalization of these companies exceeded $150 billion [1]". VCG auction originated from William Wickery, is a new auction mode based on GSP. VCG solves the problem of EFFICIENCY of GSP well by paying the final auction price of goods as well as the losing bid. However, the practical limitations of its application and the huge cost of transformation make GSP still a mainstream auction method. William Vickery's (1961) inquiry into auctions and "counter speculation" marked the first serious attempt by an economist to analyze market rules' details and design new rules to achieve superior performance. He demonstrated that a particular pricing rule makes it a dominant strategy for

bidders to report their values truthfully, even when they know that their reported values will be used to allocate goods efficiently [2]. For a long time, the way of online auction has been disputed by scholars. Both the "effectiveness" of GSP in auction and the "cost" of VCG make it difficult for advertisers to choose. In order to better choose an appropriate auction way, this article compared the profit data of the two auction ways and to find out more intuitively which kind of auction is more suitable for online auction.

1.2. Literature Review

Most scholars have conducted separate studies on GSP and VCG, including the operation mode and development history of GSP and VCG, Analysis of Bid Structures in GSP [3] show that GSP is an auction that is tailor-made for the online auction. Most of these are applied to AD auctions of search engines. Similar to Second Price Sealed Bid, each advertiser has two chances to bid, and the highest bidder wins. However, under Second Price Sealed Bid, GSP encourages advertisers to "tell the truth" only when bidding for one item, rather than multiple.

The VCG Auction in Theory and Practice [4] use a mathematical model which explains the operation process of GSP, and the result illustrates the position is higher, which means higher value, so advertisers who are willing to pay higher price can get the more obvious slot, which indicates that GSP equilibrium is effective. Internet Advertising and the Generalized Second-Price Auction: Selling Billions of Dollars Worth of Keywords mentioned that VCG solves problems such as negative externalities based on GSP operation mode [5]. The efficiency of an online auction can be effectively improved through the extra payment of the bidding amount by the winner. It can still be effective in the case of multiple auction items. Vickrey's original inquiry treated both auctions of a single item and auctions of multiple identical items, providing a mechanism in which it is a dominant strategy for bidders to report their values truthfully and in which outcomes are efficient. The mechanism is often referred to as the second-price sealed-bid auction [2]. However, an Expressive Mechanism for Auctions on the Web [6] shows that in the online auction mechanism, GSP and VCG limit the expression ability of bidders in the actual operation and do not show the preference of advertisers well. Users typically restrict the utilities to be linear in the price, with identical slopes across the items. They often require the utilities to be continuous in the price. The preferences naturally lead to nonlinear utilities in the price, such as sponsored search auctions in which part of the bidders are interested in clicks, and others are interested in impressions of Hybrid keyword search auctions [7]. The data of Internet advertising and the generalized second-price auction: Selling billions of dollars worth of keywords [1] show that GSP has not been replaced in practice. The revenue of GSP brings to big search engine companies such as Yahoo and Google, which is increasing. The annual revenue of Google advertising exceeded $150 billion in 2006. The GSP auction accounted for 98 percent of Google's total revenue in 2005. Yahoo had total revenue of $5. 26 billion in 2005, and GSP also is a big part of that, particularly at General Motors. Patrick Hummel conducted a comparative experiment on VCG and GSP to prove the influence of the number of advertising Spaces provided by different search engines on the use of VCG or GSP in the context of the online auction. He argued that even though VCG is more effective than GSP in the case of multiple AD auctions, GSP still uses more AD space than VCG if the search engine company offers less AD space (not just one AD space). And in some search engines, the amount of advertising displayed can be changed. So, for pages that display fewer ads, advertising position will be more obvious and more easily clicked by users than those with more advertising sites. Since the valuation of advertisers is expected to be different, not all competitors compete for the best AD space, also known as the first place at the same time [8]. An Optimal Mechanism for Sponsored Search Auctions on the Web and Comparison with Other Mechanisms proposed a new mechanism, Optimal (OPT) Mechanism, to solve the profit and efficiency problems of GSP and VCG in the actual operation [9].

These studies provided us with a lot of information about GSP and VCG, including the operation process and advantages and disadvantages of each auction method. Based on this information, this essay compared the two auction methods in more detail regarding profits and other aspects with the support of data. Thus, from the perspective of economics, even though relevant literature has solved the problem that the negative externalities of GSP and VCG are difficult to calculate in real society, and also find that GSP has not been replaced by other auction mechanisms so far. On the contrary, GSP has solved some problems in actual operation through continuous improvement.

1.3. Research Contents and Framework

Based on the comparison of advantages and disadvantages of GSP and VCG, the GSP auction mechanism and promotion application theory and empirical analysis, at the same time selected Google economic conditions and experimental control variables simulation, and VCG mechanism for a detailed comparison, and combined with the actual operation and demand of the current online auction market, to solve the problem of which auction method is more suitable for online auction. The framework of this paper is as follows. Firstly, this article explains the background of online auctions and the theme of this paper (which is better, GSP or VCG). Secondly, we analyze the data by comparing the

profit and efficiency of GSP and VCG. And then, based on the theoretical and empirical analysis of the results and discussion, we give the final summary.

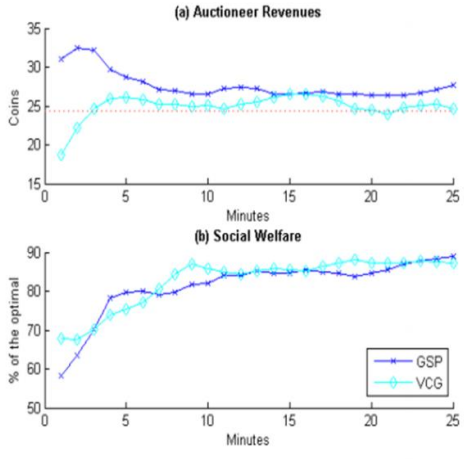
2. METHODOLOGY

2.1. Data Source

The data sources of this paper are the annual profit data of Facebook and Google from 2009 to 2020, the total advertising revenue data of Facebook and Google from 2009 to 2020, and the global market share data of major search engines from 2011 to 2021. An Experimental Evaluation of Bidders' Behavior in Ad.

2.2. Analysis of Experimental Simulation Results

The VCG auction mechanism proposed by Vickery presents a new challenge to the existing popular GSP mechanism. In An Experimental Evaluation of Bidders' Behavior in Ad, the author recruited volunteers and divided them into a group of 5 as advertisers in a consecutive bidding auction within 25 minutes. The experiment conducted data analysis after controlling variables, calculated in four different experimental conditions. Bidders change the frequency of bidding price per minute on average to compare the stability of GSP and VCG auctions and the external impact on social welfare and other experimental papers selected for analysis. Auctioneers, to predict the indirect impact on revenue and profit. Although the auction is based on the advertiser's "valuation", due to the advertiser's valuation is not necessarily accurate, it may bring error. The article analyzes GV, given valuation and DV, according to different returns, the advertiser launched valuation. In this paper, two groups of data with research significance compared with other experimental papers were selected for analysis.



By mechanism conditions

Figure 1 Influence graph of auctioneer's profit and social externality within 0-25min (Unit: Coins and % of the Optimal)

As can be seen from figure 1, GSP auction revenue is greater than VCG 10 coins in the first 5 minutes under the mechanical condition. However, GSP and VCG curves fluctuate as time goes by but approach to 25coins in 5-25 minutes. Thus, the gap between GSP and VCG is gradually narrowing, but GSP is still slightly higher than VCG. The auctioneer's income is the sum of the fees paid by advertisers at the auction. In the social welfare experiment, this essay found that VCG was higher than GSP at first, about 3 minutes before the experiment began. GSP reversed to VCG, and finally, both regions stabilized at about 80% of the optimal allocation. This shows that the social welfare of GSP and VCG is close to the same under the long-term operation, and the choice of mode has little influence on the effectiveness of social resource allocation. By comparing the fluctuation of these two charts, GSP is slightly higher than VCG in profitability. At about 6-7 minutes, the social welfare of VCG is equal to GSP at 80% of the optimal, and then, social welfare of VCG is always higher than GSP at about 5% of the optimal. Finally, at 25 minutes, their welfare both attached to the highest percentage, which is about 85%.

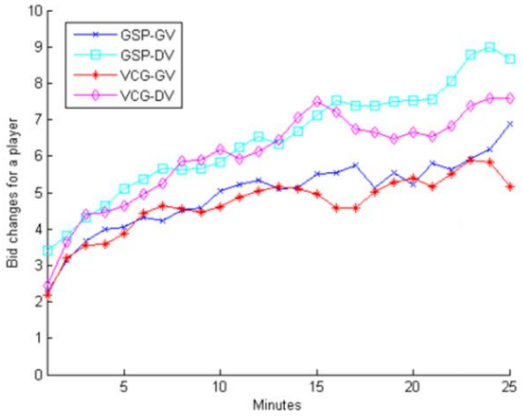


Figure 2 Price fluctuation chart of advertiser auction bidding within 0-25 minutes (Unit: times)

But from figure 2, in the first 10 minutes, GSP and VCG auction has a similar impact on the bidder, And DV are slightly higher than the GV. The price curves are staggered in pairs, which shows in the case of not clear valuation. Advertisers tend to constantly change the auction prices, embody the advertisers in the process of auction constantly learn from experience and adjust the value to obtain benefit maximization behavior. The bidding changes fluctuated greatly in the first 5 minutes for the four curves and tended to be stable in 2-25 minutes. The bidding changes were nearly 5 or 6 times per minute for the GV curve, while for the DV curve, the bidding changes were nearly 6 or 7 times per minute. Compared with the case of GV, DV is more similar to the auction in real life because the valuation is not directly known and often depends on the situation of the

advertiser. Therefore, DV's fluctuation curve is more valuable for reference. For GV curve, VCG and GSP show similar curve changes, indicating that VCG and GSP have similar effects on bidding fluctuations in this experimental case. With the development of time, the two sides tend to be stable. However, for DV curve, VCG and GSP showed different trends after 15 minutes. On the basis of both sides gradually tending to stability, GSP was significantly higher than VCG fluctuation, and the average bidding change was about 1 more time per minute, which meant that GSP was slightly less stable than VCG, and the fluctuation value was obvious. In the subsequent improvement experiment, we can learn some strategies from VCG to minimize bid volatility.

2.2. Actual profitability analysis

This article analyze and calculate the data based on a statistic analysis of Facebook and Google's annual and AD revenue reports for 2009-2020. Because advertising revenue mainly refers to the profits brought by advertising auction, which is closely related to the company's auction mechanism. Since Facebook adopts the VCG auction mechanism, while Google adopts the GSP auction mechanism, So selecting Facebook and Google as the research objects to represent the actual profitability of GSP and VCG. Since the scale and main direction of the two companies are not the same, it is not practical to directly compare the profits brought by advertising. Therefore, this essay studies the proportion of advertising profits in the total annual profits to explore the actual profitability of GSP and VCG respectively. Since 2020, the COVID-19 epidemic has gradually spread to the world, and the economy of all industries has been affected to varying degrees. Therefore, the annual revenue and advertising revenue of Google and Facebook will also be inevitably affected. Therefore, this article excludes recent years' data to avoid external factors interfering with our auction revenue analysis. This essay selected the data in a few years after Google adopted GSP and Facebook adopted VCG, and conducted data analysis under the condition that the GSP mechanism was relatively mature and perfect, finally eliminating the revenue error caused by the incomplete and loophole of GSP mechanism.

For every $1 spent on Google ads, companies make $2 in revenue, with an average cost per click (CPC) of $2. 69 for search website and $0. 63 for display Website. On Facebook ads, the company's CPC was $0. 97. Under GSP, advertisers quote per click their quote times the estimated CTR to determine the AD's approximate value and thus the AD's placement. Specifically, the highest bidder (bid) is designated as the highest position. The second highest is designated as the second-best, and so on. Then, the winner of each AD spot will pay the lowest cost per click for that spot.

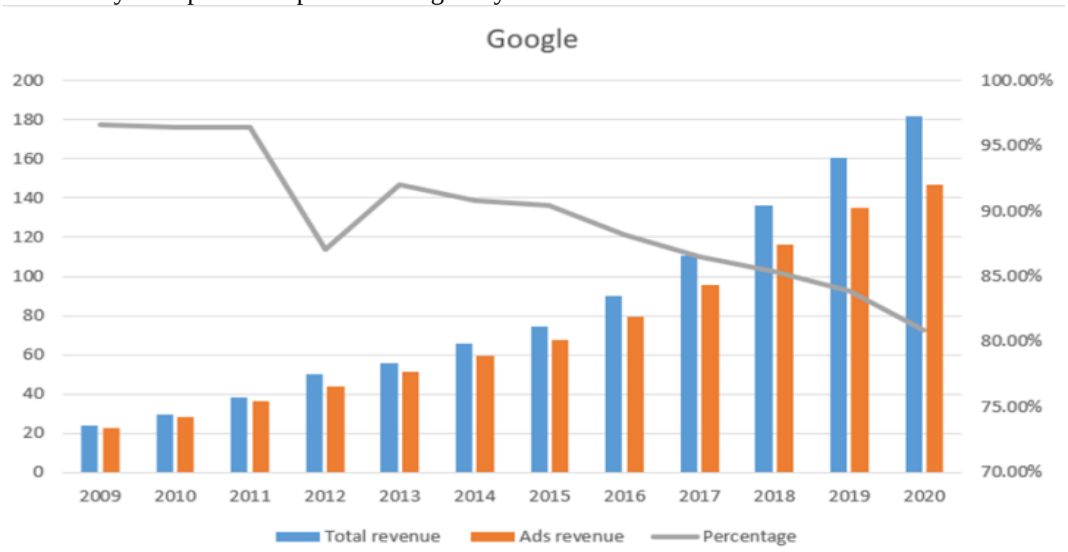


Figure 3 Proportion chart of Google's advertising revenue in total annual revenue from 2009 to 2020 (Unit: billion, %)

As shown in Figure 3, since Google adopted the GSP auction method, Google's annual revenue has increased year by year, and the marginal annual revenue has increased year by year. As can be seen from Table 1, Google's annual revenue and advertising revenue are both showing significant and rapid growth. Since 2017, Google's annual revenue has exceeded 100 million yuan. The overall development trend is good, and the economy is developing rapidly. Google's advertising revenue and Google's annual revenue showed a consistent growth rate, fully demonstrating that Google's annual revenue and advertising revenue are closely linked. The GSP auction mechanism adopted by Google for advertising profit shows that Google's GSP mechanism makes Google's profit close to Google's annual revenue. When we calculate the ratio of Google's advertising revenue to Google's annual revenue, Google's advertising revenue accounts for nearly 90% can be found in the essay. Based

on this, and also can analyze that in the process of Google's use of GSP auction in these years, GSP has created a lot of profits and advantages for Google, which is the core part of Google's economic growth.

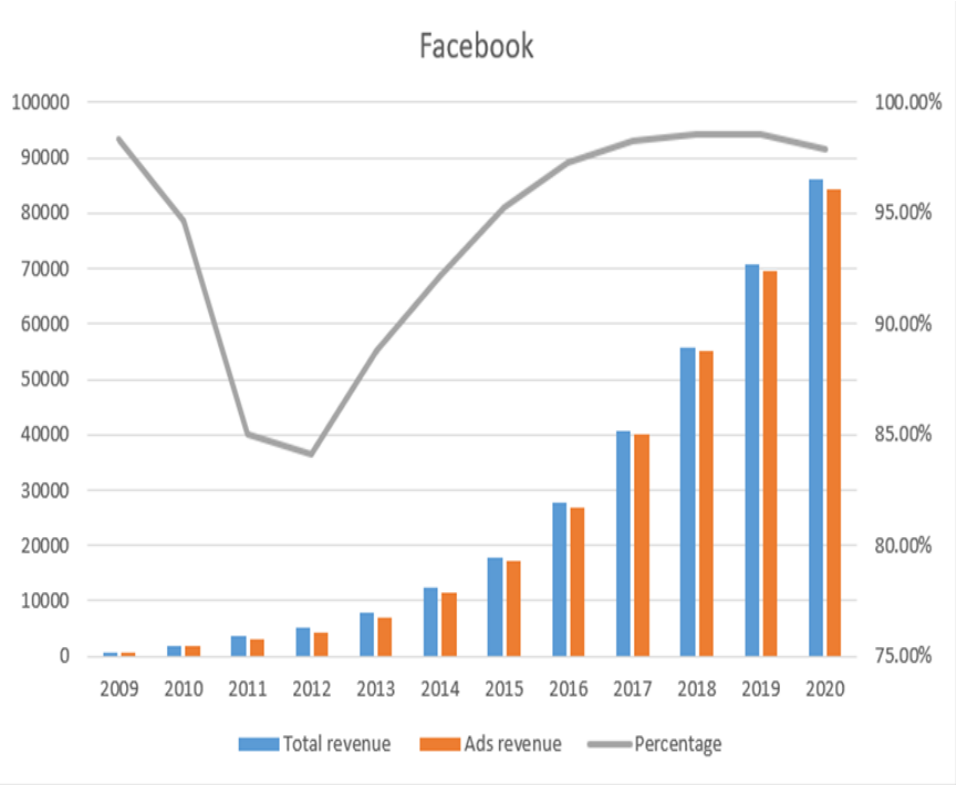


Figure 4 Ratio of Advertising revenue to total annual revenue of Facebook from 2009 to 2020 (Unit: million, %)

As shown in figure 4, the annual revenue of Facebook increases year by year, while the growth rate of marginal annual revenue decreases year by year. Thus, the growth rate of advertising revenue increases year by year, and the growth rate of marginal annual revenue increases year by year. As a result, Facebook's AD revenue has grown at the same rate as Google's annual revenue, demonstrating the close link between Google's annual revenue and AD revenue. When calculating the percentage of advertising revenue in total revenue, the percentage of advertising revenue dropped sharply from 2010 to 2012, related to Facebook's corporate policies or market conditions. After that, the percentage kept growing steadily and gradually stabilized in 2016. After that, however, there was a downward trend, and the future development trend remains to be seen.

Joint figure 3 and figure 4 percentage points data, the advertising revenue in this type of search engine occupies a large proportion, it directly shows the AD auction mechanism of the effect of advertising will be directly related to the company's profitability, therefore, what the auction mechanism is particularly important for Internet companies earnings. Facebook's share of AD revenue from VCG auctions continues to rise, from 84％ in 2012 to 97. 8％ in 2020. We preliminarily concluded that Facebook entered the auction market later than Google and used VCG rather than GSP as the auction method. Hence, its annual revenue grew faster and the proportion of advertising revenue grew faster. But Google advertising company USES the GSP auction proportion declining in recent years, we think of do not represent the GSP no VCG in profit. Still, we think it's because Google use GSP mechanism for many years, GSP processes become relatively mature and stable, and it can be seen from figure 3. However, the decline in advertising revenue accounted for. However, Google's total revenue and advertising revenue did not decline, and Google's advertising revenue reached more than 140 billion in 2020.

2.3. Real market distribution analysis

MSN currently uses GSP auctions and their variants (Bing), Ask. com, and many smaller search engines, while VCG auctions are currently only used by Facebook. Based on the global desktop market share of the major search engines for January 2010 to June 2021 provided by Statistics, we have compiled the top three search engines with the highest market share in January of each year. Furthermore, research shows that these three search engines also use GSP auction mechanism, which shows the prevalence of GSP in the auction market.

Table 1. Worldwide desktop market share of leading search engines from January 2010 to January 2021 (Unit: %)

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Google	90. 1%	91. 5%	90. 5%	89.0%	88. 1%	88. 4%	89. 1%	87. 4%	90.0%	87. 4%	85. 9%
Bing	4. 27%	3. 56%	3. 19%	4. 04%	4. 53%	4. 85%	4. 59%	5. 79%	3. 99%	5. 53%	6. 84%
Yahoo !	3. 96%	3. 33%	2. 88%	2. 65%	4. 13%	3. 30%	3. 08%	3. 07%	2. 84%	2. 83%	2. 76%

GSP is still the most popular among all online auction mechanisms. According to The Table 1, Google's market share of online auction reached a peak of 91.5% in 2012 and a minimum of 85.9% in 2021, which shows the importance of online auction to Google, especially GSP. The upstart Bing has only a small market share, but overall, GSP is still the dominant online auction mechanism, with an average of 90%.

3. RESULTS AND DISCUSSION

This paper mainly compared GSP and VCG two different online auction methods, and combined with literature review and data analysis to study which of the two auction methods GSP and VCG can maximize the interests of advertisers. Among them, the paper carries out data analysis for data analysis from three aspects: experimental simulation results, actual profitability, and real market distribution. Specifically, in the aspect of experimental simulation, we select the fluctuation trend of price index of advertiser's auction bidding within 0-25 minutes and the influence of auctioneer's profit and social externality within 0-25 minutes. The study finds that GSP is slightly less stable than VCG, but it brings a slightly higher income than VCG. In general, the social welfare impact of GSP and VCG is similar. It shows that the improvement of VCG will make GSP more stable and keep the overall profit advantage. In terms of actual profitability, this article selects Google and Facebook from 2009 to 2020, the proportion of advertising revenue in the total annual revenue, and profitability change. The research finds that in reality, advertising auction accounts for a large proportion of the revenue of such advertising companies and both VCG and GSP have profitability. It shows that choosing a good advertising auction mechanism will bring huge profits to advertising companies. For the actual market distribution, this essay select the Worldwide Desktop Market share of leading Search Engines from January 2010 to January 2021. GSP mechanism almost occupies the advertising market, indicating that the existing GSP mechanism is very popular with advertising companies. If they want to change the existing mechanism, they need to consider the cost of change.

Different from the passage of The lovely but Lonely Vickrey Auction, our research results questioned the advantage of VCG that VCG compensates for The negative externalities of GSP. Internet Advertising and the Generalized Second-price Auction: Sales Billions of Dollars' Worth of Keywords data are similar, supporting the fact that GSP is generating significant revenue and has a majority of the advertising market. We believe that the inconsistent conclusions are that theoretical analysis and simulation experiment have different data processing methods, and negative externalities are difficult to estimate.

4. CONCLUSION

This paper mainly studies that which GSP or VCG is more suitable for the current online auction environment. We mainly compare and analyze three aspects: experimental simulation results, actual profitability and real market distribution. For charts and data analysis and comparison, we found that GSP had less profitable than VCG in terms of auctioneers, and Google's advertising revenue peaked about 148 billion dollars in 2020. Finally, we think the GSP auction environment is more suitable for the current network, the reason is that the GSP operation mechanism is used more, improvement and development of the relatively stable for a long time so, in the actual profitability and the analysis of the reality can be seen in the GSP in the "profits" is better than VCG. For this article, we advocate the continued use of GSP and hope that it will be improved over time, as we believe that GSP has been developed and used over the years and will be better than some of the current new mechanisms like Optimal (OPT) etc. So more stable, that does not have a lot of new problems.

Our paper mainly discusses the specific advantages of GSP compared with VCG in online auctions. We believe that GSP should continue to be improved and used. In the first part, we introduced the basic definition of network auction and put forward the main idea of this article content. The second part we from three aspects: "the experimental simulation results and actual profitability, real market distribution" for data analysis, contrast the GSP and VCG found the advantages and disadvantages of the GSP, based on the data analysis conclusion. In addition, considering the stability of various auction methods and profits in the actual operation, we believe that GSP should not be replaced but should be continuously improved and continued to be used.

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