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ACCEPTED MANUSCRIPT

Bounding the inefficiency of outcomes in generalized second price auctions*

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Abstract

The Generalized Second Price (GSP) auction is the primary auction used for monetizing the use of the Internet. It is well-known that truthtelling is not a dominant strategy in this auction and that inefficient equilibria can arise. Edelman et al. (AER, 2007) and Varian (IJIO, 2007) show that an efficient equilibrium always exists in the full information setting. Their results, however, do not extend to the case with uncertainty, where efficient equilibria might not exist.

In this paper we study the space of equilibria in GSP, and quantify the efficiency loss that can arise in equilibria under a wide range of sources of uncertainty, as well as in the full information setting. The traditional Bayesian game models uncertainty in the valuations (types) of the participants. The Generalized Second Price (GSP) auction gives rise to a further form of uncertainty: the selection of quality factors resulting in uncertainty about the behavior of the underlying ad allocation algorithm. The bounds we obtain apply to both forms of uncertainty, and are robust in the sense that they apply under various perturbations of the solution concept, extending to models with information asymmetries and bounded rationality in the form of learning strategies.

We present a constant bound (2.927) on the factor of the efficiency loss (*price of anarchy*) of the corresponding game for the Bayesian model of partial information about other participants and about ad quality factors. For the full information setting, we prove a surprisingly low upper bound of 1.282 on the price of anarchy over pure Nash equilibria, nearly matching a lower bound of 1.259 for the case of three advertisers. Further, we do not require that the system reaches equilibrium, and give similarly low bounds also on the quality degradation for any no-regret learning outcome. Our conclusion is that the number of advertisers in the auction has almost no impact on the price of anarchy, and that the efficiency of GSP is very robust with respect to the belief and rationality assumptions imposed on the participants.

JEL Classification: D44 – Auctions

Keywords: auction design, equilibrium analysis, price of anarchy, bayesian games, generalized second price auction, keyword auctions

*Preliminary versions of some of the results in this paper appeared in Paes Leme and Tardos, FOCS'10 [29], Lucier and Paes Leme, EC'11 [24], and Caragiannis, Kaklamanis, Kanellopoulos and Kyropoulou, EC'11 [8].

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