Stakeholder-oriented Decision Support for Auction-based Federated Learning

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Abstract
Auction-based federated learning (AFL) is an important area of FL incentive mechanism design. It effectively incentivizes high-quality data owners (DOs) to participate in data consumers’ (DCs, i.e., servers’) FL training tasks. However, AFL is still evolving, with existing methods primarily addressing optimal DC-DO matching or DC selection problems in monopoly markets. To enhance the practicality of AFL, we introduce stakeholder-oriented decision support in AFL. This facilitates optimal and strategic decision-making for all stakeholders, improving the efficiency and sustainability of the AFL ecosystem.

1 Introduction
Federated Learning (FL) [Yang et al., 2019] has emerged as a useful collaborative machine learning (ML) paradigm by enabling collaborative model training without the need to expose local data, thereby enhancing data privacy and user confidentiality. Prevailing FL methods often assume that data owners (DOs, a.k.a. FL clients) are ready to join FL tasks by helping data consumers (DCs, a.k.a. FL servers) train models. In practice, this assumption might not always hold due to DOs’ self-interest and trade-off considerations. To deal with this issue, the domain of auction-based federated learning (AFL) has emerged [Tang et al., 2024b].

As shown in Fig. 1, the main actors in AFL include the auctioneer, DOs and DCs. The auctioneer functions as an intermediary, facilitating the flow of bid requests (i.e., asking prices and available data resources) from DOs to DCs. DCs then determine their bid prices to be submitted to the auctioneer. The auctioneer then consolidates the auction outcomes and informs the winners about the match-making results. To deal with this issue, the domain of auction-based federated learning (AFL) has emerged [Tang et al., 2024b].

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However, this field is still in its early stages, with most existing works focusing on one aspect of the auctioneer’s decisions, such as optimal DC-DO matching and pricing to maximize social welfare or minimize social cost for the FL ecosystem [Xu et al., 2023], or one aspect of the DCs decision on selecting DOs [Jiao et al., 2020]. This leaves various issues unresolved, including how to enhance the competitiveness of the auctioneer, how DCs should bid for DOs and how DOs allocate their resources.

2 Research Directions and Contributions
To deal with these issues, our research aims to provide intelligent stakeholder-oriented decision support to all three types of stakeholders: DCs, the auctioneer, and DOs. Our goal is to help them make optimal and strategic decisions to maximize their own objectives. Specifically, we plan to achieve the following breakthroughs in stakeholder-oriented decision support in AFL:

1) **DC-oriented decision support**: Existing approaches [Jiao et al., 2020; Le et al., 2020; Zhou et al., 2021; Yuan et al., 2021; Zhang et al., 2021] for DCs often assume a monopoly AFL marketplace with only one DC. However, this assumption may not hold in open collaborative AFL marketplaces where multiple DCs simultaneously compete to attract DOs. To address this, we aim to provide DC-oriented decision support from the perspective of helping them bid optimally for DOs in a cost-effective manner, while maximizing their key performance indicators (e.g., accumulated expected utility) within or without the budget limit, while also considering the health of the whole ecosystem.

2) **DO-oriented decision support**: DOs need to determine the amount of resources to commit and the reserve price in order to maximize their profit in the auction process. However, few existing works have studied this problem, resulting
in potential loss for DOs due to low bids from DCs or over-
high resource consumption. To bridge this gap, we aim to
develop dynamic pricing strategies for DOs to support them
in optimally determining the number of committed resources
and the corresponding floor price to maximize their benefits,
especially for those with high-quality data resources.

3) **Auctioneer-oriented decision support**: Existing meth-
ods [Xu et al., 2023; Roy et al., 2021; Mai et al., 2022;
Wang et al., 2023] for the auctioneer mainly focus on opti-
mal DC-DO matching and pricing for social welfare maxi-
mization and social cost minimization, assuming a monopoly
data trading platform. However, in reality, there may be mul-
tiple trading platforms with different auction mechanisms co-
ordinated by different auctioneers. Therefore, the auctioneer
needs to improve its competitiveness by developing attractive
auction mechanisms to attract new participants and enhance
the stickiness of existing participants. To address this, we
aim to frame the attractiveness of the auction platform from
the perspective of fairness to both DOs and DCs, and develop
selection time-aware and contribution-aware auction mecha-
nisms to achieve selection fairness for DCs and contribution
fairness for DOs, respectively.

Overall, our research aims to provide intelligent
stakeholder-oriented decision support in AFL to help all three types of stakeholders, i.e., DCs, DOs, and auc-
tioneers, make optimal and strategic decisions to achieve their
desired objectives and enhance the overall efficiency and
effectiveness of the AFL ecosystem.

Our current research focuses on DC- and DO-oriented de-
cision support. Specifically, for the DCs, we have proposed
FedBidder [Tang and Yu, 2023b], the first-of-its-kind bidding
strategies, to help them bid for DOs in the competitive AFL
marketplace with the aim of maximizing their utilities under
the budget constraint. In addition, taking into consideration
the intricate relationships among DCs, which can be simul-
taneously competitive and cooperative, we also propose to
model the AFL ecosystem as a multi-agent system and pro-
pose MARL-AFL [Tang and Yu, 2023a] to guide DCs in
strategically bidding towards an equilibrium with desirable
overall system characteristics. In addition, we have intro-
duced the first decision support method for DOs, called PAS-
AFL [Tang et al., 2024a]. It offers a systematic approach
for joint decision-making on AFL bid acceptance, task sub-
delegation, and pricing. This is based on Lyapunov optimiza-
tion to maximize utility.

### 3 Future Works

In our future research, we plan to continue our focus on DC-
oriented decision support, refining our bidding strategies to
be more cost-effective and bias-free, thereby enhancing DCs’
stickiness and reliance on the market, and attracting more
DOs to join. We will then extend our research to provide
support to DOs by developing dynamic pricing strategies to
maximize their profit in the auction process. Finally, we will
address the needs of auctioneers by designing fairness-aware
auction mechanisms that promote fairness and competitive-
ness among DCs and DOs. Overall, our research aims to con-
tribute to the improvement of the overall performance and
health of the AFL ecosystem by providing decision support
to all stakeholders.

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