How Ethereum Utilizes Auctions to Mitigate Negative MEV Impact

Game Theory Term Project

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1 Introduction

In the Ethereum Proof-of-Stake (PoS) based consensus mechanism, participation in the consensus is conditioned by staking a predetermined amount of Ethers (Ethereum's native currency). Consensus participants are called validators and their responsibilities include building and proposing a block when selected, checking the validity of the included transactions and subsequently attesting (voting) for the blocks that should be included in the final chain. This helps the chain to actively grow while still ensuring the safety.

The timeline in Ethereum is divided into 12-second long slots and 32-slots long epochs. Every slot, a validator is selected to propose a block and is incentivized to do so by rewards defined by the incentive mechanism. The block is created by combining transactions waiting to be processed in the mempool, with each transaction offering a reward for the proposer that selects it for their block. Besides the rewards originated from the fees, block proposers can also profit from the Maximal Extractable Value (MEV) [4].

MEV allows proposers to increase their reward by ordering, including and excluding the transactions in the block. As shown in Figure 1, the profit gained from MEV can be significant and proposers are incentivized to strategically sort transactions to gain MEV profit.

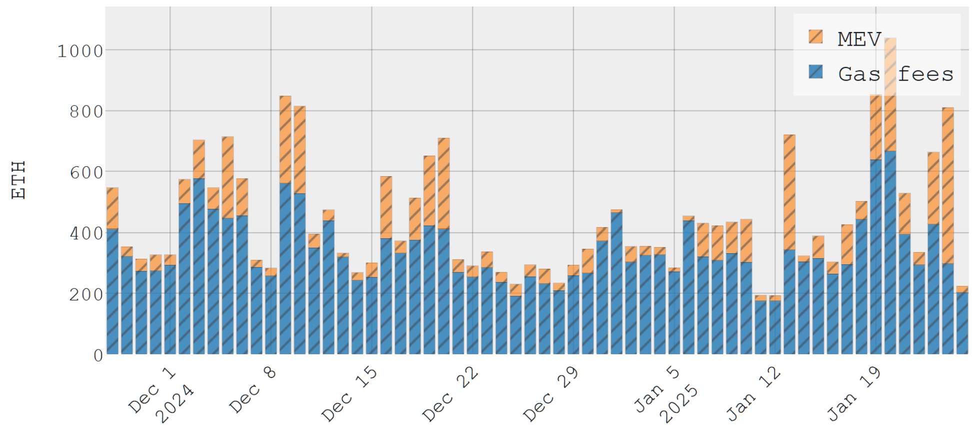

Figure 1: The total daily revenue acquired from the fees and the MEV [6].

While MEV is an important part of many mechanisms, it can also have negative impact on the consensus of PoS Ethereum. The main concern is the centralization of validators. Solo validators that staked their 32 Ethers to participate in the consensus may not have so many opportunities to optimally extract MEV compared to stakers that are a part of a staking pool that has powerful tools to capture MEV. This may encourage validators to join the staking pool just for the MEV opportunities [3].

One of the mechanisms that has been proposed to mitigate these negative effects is the Proposer-Builder Separation (PBS). This project aims to generally describe the PBS mechanism and then take a closer look at how the mechanism utilizes auctions. The architecture of the PBS is described in section 2, the blockspace auction of the MEV-Boost implementation is analysed in section 3 and in section 4, the Order Flow Auctions are shortly introduced.

2 The Proposer-Builder Separation Mechanism

The Proposer-Builder Separation is a proposal that suggests the separation of the block proposer and block builder roles. This allows even individual validators to access MEV opportunities through a marketplace of blocks created by specialized builders [3]. This project describes this mechanism as implemented by Flashbots in MEV-Boost. MEV-Boost is a middleware that allows proposers to access the marketplace, utilizing auctions in their architecture [2]. As of January 2025, more than 90 % of proposed blocks have been created using MEV-Boost [6] and the adoption success has encouraged discussions about implementing PBS directly as apart of the Ethereum consensus mechanism in form of enshrined PBS (ePBS) [5]. In the MEV-Boost architecture, there are the following roles that are shown in Figure 2 and further described in this section: proposers, builders, relays and searchers.

Builders Builders are specialized on creating blocks with the most profitable MEV. They utilize simulations to try and find the best transactions ordering using algorithms like First Come, First Serve or First Price Auctions. The goal of the builders is to partake in the auction, described in section 3, where only the highest bid wins, meaning the goal is to create a more profitable block than other builders [2].

Searchers While builders utilize the public mempool of transactions in their efforts, there is also another source of transactions: the private order flow. These transactions are not public, instead they are only accessible by one or many builders, and can originate from decentralized applications or be found by searchers. Searchers create bundles of profitable transactions and offer them to builders who can profit by prioritizing these transactions and getting payments as a reward. One of the mechanisms of bundles exchange between searchers and builders is called Order flow auctions (OFAs), further described in section 4 [10].

Relays The mediator for the block exchange between the builder and the proposer is called relay. Relay serves as an auctioneer in the first-price auction, further described in section 3. Relay selects the highest bid made by a builder, validates the winning block and sends its header to the proposer, hiding its contents until the proposer commits to the block by signing it. This ensures the block contents and its MEV cannot be stolen from the builder [8].

Proposer Compared to the role of proposers in the consensus, where the proposer both builds the block and then proposes it, in PBS proposers only have to receive the block from the relay, sign its header and then propose the block once the auction is over.

Mechanism evaluation Although the mechanism mitigates some of the negative MEV impact, it is still actively researched and the current design does have drawbacks. Based on an analysis by Öz et al. [10], builders' ability to find a profitable block composition and win MEV-Boost auctions is significantly reliant on their access to the private order flow, preferably shared exclusively with them. This creates a difficult situation, since builders need to have a high enough market share to access exclusive order flow but such a market share cannot be obtained without the access [10]. Wu et al. [7]

have described the market as oligopolistic and centralized due to the low amount of dominant builders. Additionally, Wu et al. analysed the bidding strategies in MEV-Boost auctions and discovered that builders are incentivized to collude by marginal outbidding rather than to compete by declaring their true valuation [9].

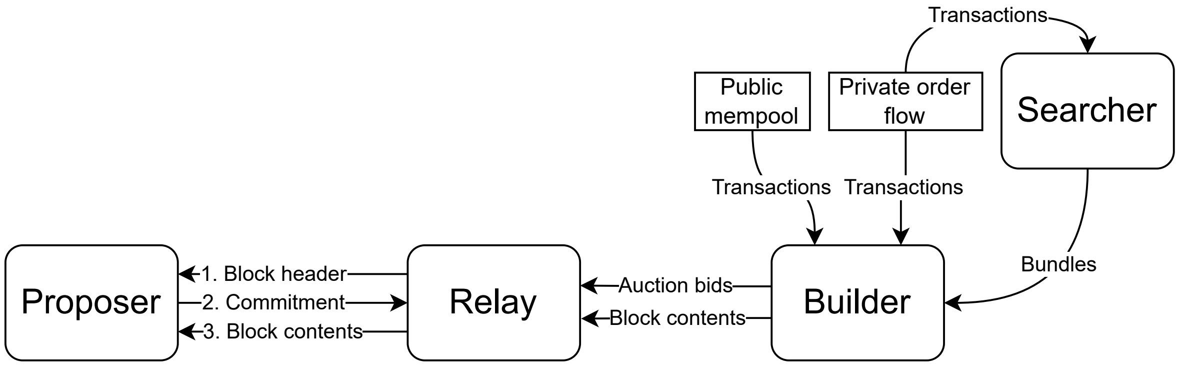

Figure 2: The architecture of PBS used by MEV-Boost [2].

3 MEV-Boost Auctions

This section describes the MEV-Boost auctions of blockspace based on the game-theoretic MEV-Boost auction models defined by Wu et al. [8].

3.1 Auction analysis

Participants The set of players (buyers) in the auction represents the builders: $N = \{1..n\}$. The auctioneer is the relay that mediates the auction. The seller is the proposer that was selected to propose a block in the current slot.

Subject of the auction Players attempt to turn a profit by attempting to building the most profitable block that would get selected by the auctioneer and proposed to be included in the canonical Ethereum chain. Therefore, the subject of the auction is the blockspace of the current block proposer (auctioneer).

Bids and bidding strategies The bid of player i at time t is defined as $b_{i,t} = \beta_s(x_{i,t})$. $\beta_s : X \to \mathbb{R}_+$ is a function that represents the bidding strategy s of each player. $x_{i,t} \in X$ is a vector of input values that impact the bidding strategy s and therefore also the bid $b_{i,t}$. The values are as follows:

- **Public signal** $P(t)$ that represents the sum of MEV from all of the transactions available in the public mempool at time t.
- **Private signal** $E_i(t)$ that represents the sum of MEV from all of the transactions from the private mempool available to the player i at time t. These are typically bundles of transactions

from the private mempool that are shared by searchers. This process is further described in section 4.

- **Profit margin** pm_i represents the risk tolerance and the profit expectations.
- **Current highest bid** up to time t defined as $max_{j \in N} b_{j,k}$ where k, $k \leq t$, is the time of the highest bid.
- **Latency** caused by player's network connectivity and relay's processing speed.

Bid submission Players submit bids during the whole duration of the auction, defined by the interval $[0, T]$. At time T, the winning bid is selected. T is usually not fixed due to network latency or different bidding strategies, which affect the duration of the auction, although the value of T is usually around 12 seconds, tallying with the duration of one slot.

Winner selection The builder with the highest bid is selected and the header of the block is sent to the proposer by the relay, followed by the contents of the blocks after the header gets signed by the proposer. A more profitable block allows the builder to offer a higher bid, meaning the selected block is one of the most profitable blocks created.

Players' valuation The player's valuation is the highest possible bid for the auction to be still profitable to the player in case the player wins the auction. For player i at time t, it is defined as the difference between the total MEV extracted from the public and private mempool and the player's profit margin: $v_i(t) = S_i(t) - pm_i$, where $S_i(t) = P(t) + E_i(t)$.

Players' profit The player's profit from their winning bid is computed as the difference between the total MEV extracted from the public and private mempool and the offered bid that is paid to the auctioneer (builder):

$$\begin{cases} S_i(t_w) - b_{i,t_w} & \textit{if } b_{i,t_w} = \textit{the current highest bid at time } T \\ 0 & \textit{otherwise} \end{cases} \tag{1}$$

where t_w is the time of the winning bid and $S_i(t_w) = P(t_w) + E_i(t_w)$.

Interaction among players The auction is open, meaning players can see bids of other players that have submitted them to the same relay. While players do not communicate with each other directly, their bidding strategies can be influenced by other submitted bids and players have the ability to collude rather than compete [9, 8].

3.2 Bidding Strategies

Wu et al. have described several bidding strategies in the MEV-Boost auctions and analysed their effectiveness in various groups based on the strategies of other players, including the impact of

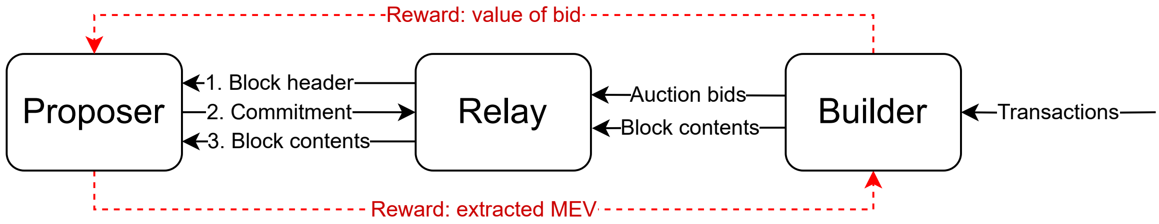

Figure 3: The design of the MEV-Boost auction [8].

external influences like latency, revealing time and auction termination time. The studied strategies are as follows [8]:

Naive $\beta_{naive}(x_{i,t}) = v_i(t)_+$ player i bids as long as $S_i(t)$ is higher than pm_i, meaning their valuation $v_i(t)$ is positive.

Adaptive $\beta_{adaptive}(x_{i,t}) = min\{v_i(t), max_{j \in N}\{b_{j,k} : k \leq t\} + \delta\}_+$ player i only bids if they can outbid the current highest bid by δ while keeping their valuation $v_i(t)$ positive. Otherwise, they adopt the naive strategy.

Last Minute $\beta_{lastMinute}(x_{i,t}) = v_i(t) \times 1\{t \geq \theta\}$, where θ is the time when the player starts to bid according to their valuation. Last-minute player i bids according to their valuation as late as possible before the auction termination, giving less reaction time to the adaptive players, but risking missing the auction time window.

Bluff $\beta_{bluff}(x_{i,t}) = b_{i,bluff} \times 1\{t < \theta\} + v_i(t)_+ \times 1\{t \geq \theta\}$, where θ is the time when the player starts to bid according to their valuation. Player i submits a bid that is higher than their valuation and reverts their bid by the end of the auction, submitting their real valuation. Player i risks negative profits in case the bid is not reverted before the auction ends. In the model, bid can be cancelled by replacing the higher bid with a lower one for the given block, although the cancellation is not always honoured in the real auction.

4 Order Flow Auctions

Order Flow Auctions (OFAs) provide a way to reward the users for providing their transactions using the private order flow which is the most important aspect in the builders' competition, as described in section 2. In OFAs, the searchers submit their bids to gain the exclusive access to the transactions. The sellers in the auction are the entities who produce the transactions like the users, the decentralized finance applications or the wallets. The winner of the auction is then selected based on different values like the max rebate to the user, the max fees paid or the best price offered. This way, a portion of the profit is paid back to the transaction producers. There are many OFA implementations that differ in the auction types, with most of them being sealed-bid first-price auctions. In the current PoS Ethereum, there are concerns about OFAs regarding the centralization in the PBS architecture. As a response, Flashbots has started the development of SUAVE, a platform for OFAs that attempts to decentralize the block building process [1].

5 Conclusion

The PBS mechanism has been proposed to mitigate the negative impact of MEV on the consensus and while the current most adopted implementation MEV-Boost by Flashbots has been successful, there are still drawbacks that have to be worked on regarding the auctions like the oligopolistic tendencies of the market, the centralization in different parts of the mechanism and the collusion of the builders, lowering the level of competition in the auctions. The game-theoretic auction model of the MEV-Boost of the auction has been described, including various bidding strategies. The order flow auctions have also been introduced, including their negative effects on the centralization and the project SUAVE that attempts to minimize these effects. The active research and development in this area ultimately aims to improve the mechanism and include it directly in Ethereum's consensus mechanism in the from of ePBS.

References

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