Let Leaders Play Games: Improving Timing in Leader-based Consensus

Extended Abstract

Rasheed M
IIIT Hyderabad
Hyderabad, India, India
mohammad.ahmed@research.iiit.ac.in

Parth Desai
IIIT Hyderabad
Hyderabad, India, India
parth.desai@research.iiit.ac.in

Sujit Gujar
IIIT Hyderabad
Hyderabad, India, India
sujit.gujar@iiit.ac.in

ABSTRACT

In leader-based blockchains, the leader – block *proposer* – is known in advance for each slot. A fast (or low-latency) proposer may delay the block proposal in anticipation of more rewards from the transactions that would otherwise be included in the subsequent block. Deploying such a strategy by manipulating the timing is known as *timing games*. Moreover, proposers who play timing games essentially appropriate MEV (additional rewards over transaction fees and the block reward) that would otherwise accrue to the next block, making it unfair to subsequent block proposers. We propose a double-block proposal mechanism, 2-Prop to curtail timing games. 2-Prop selects two proposers per slot to propose blocks and confirms one of them. We design a reward-sharing policy for proposers based on how quickly their blocks propagate. In the induced game – *Latency Game*, we show that it is a Nash Equilibrium for the proposers to propose the block without delaying under the homogeneous network conditions. Under heterogeneous network conditions, a faster proposer would prefer not to delay unless the other proposer is extremely slow. Thus, we show the efficacy of 2-Prop in mitigating the effect of timing games.

CCS CONCEPTS

• **Theory of computation** → *Solution concepts in game theory.*

KEYWORDS

Blockchain; MEV; Timing Game; Nash Equilibrium

ACM Reference Format:
Rasheed M, Parth Desai, and Sujit Gujar. 2026. Let Leaders Play Games: Improving Timing in Leader-based Consensus: Extended Abstract. In *Proc. of the 25th International Conference on Autonomous Agents and Multiagent Systems (AAMAS 2026), Paphos, Cyprus, May 25 – 29, 2026*, IFAAMAS, 3 pages. https://doi.org/10.65109/KDLJ1170

1 INTRODUCTION

Leader-based consensus protocols progress in rounds, also known as *slots*. In each slot, a committee of *validators* adds a new block to the ledger. Typically, all the validators, particularly the proposer for the next slot, are known in advance. The validator that proposes the next block is known as *proposer*, and the rest who validate and attest to the proposed block are known as the *attestors*. A proposer publishes its block at the beginning of the slot, $t = 0$, the attestators attest the block receieved till $t = \tau_1$. The block is confirmed if it obtains K attestations.

A proposer with access to a faster network can strategically delay the block proposal by $\delta \in (0, \tau_1]$, to collect more fees and extract more MEV from the transactions arriving from $t = 0$ to $t = \delta$. Such manipulation of the timing of block proposal is known as *timing games* [11]. The timing game is prevalent in Ethereum [10], and therefore, we outline the main ideas of this paper in this context. However, our results hold for any leader-based blockchain protocol where the leader for each slot is known in advance.

Contributions. (i) We propose a double-block proposal mechanism, 2-Prop: two proposers propose their blocks, (ii) we provide a simple yet effective method to confirm one of the blocks based on the attestations timing; (iii) we propose reward sharing between the proposers. (iv) For analyzing 2-Prop, we model it as a 2-player game, *Latency Game*. We prove that, in the induced game, (a) under homogeneous settings, it is a Nash Equilibrium for the proposers not to delay block proposal, (b) under heterogeneous settings, we show that a faster proposer delays only when the expected time for the block to reach an attestor is close to τ_1.

2 MODELLING

Network. Let f_P denote the probability density function (PDF), with mean μ_P, of the random variable representing the time at which a block sent by P arrives at an attestor. For f_p, we assume (i) it is unimodal with support $[0, \infty)$ similar to prior research works [1, 5, 6, 9] including analysis on Ethereum network [2, 7] and (ii) it is reasonably peaked and propose a *restricted* L^2-norm that captures how concentrated the PDF is in a given interval (see Def. 1).

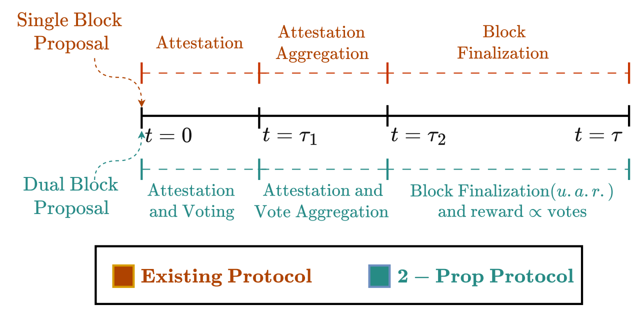

Figure 1: Progression within Slot

Proc. of the 25th International Conference on Autonomous Agents and Multiagent Systems (AAMAS 2026), C. Amato, L. Dennis, V. Mascardi, J. Thangarajah (eds.), May 25 – 29, 2026, Paphos, Cyprus. © 2026 International Foundation for Autonomous Agents and Multiagent Systems (www.ifaamas.org). https://doi.org/10.65109/KDLJ1170

Definition 1 (Restricted L^2 norm). *A* restricted L^2 norm *of f_P on interval $[a, b]$, $L^2_{f_P}[a, b]$ is given by*

$$L^2_{f_P}[a,b] = \left(\int_a^b f_P(x)^2 \, dx \right)^{1/2}$$

In this work we assume that $L^2_{f_P}[0, \tau_1] \geq \frac{1}{2\sqrt{\tau_1}}$, as otherwise f_p would have maximum mass between $[\tau_1, \infty)$, which implies most of the blocks will be missed. Our protocol works without this assumption; however, analytical guarantees become challenging.

Protocol. We propose 2-Prop as a modification to the leader based consensus protocol Ξ, with a validator selection function $\mathscr{V}(\mathfrak{L}^\ell, n)$ that outputs (i) $n + 2$ nodes as validators $\mathbf{V}^\ell$ and (ii) two among these validator as the block proposers, $\mathbf{P}^\ell = \{P_0, P_1\}$. The remaining validators will be attestors $\mathbf{A}^\ell = \{A^\ell_0, \ldots, A^\ell_{n-1}\}$. Both proposers, P_0 and P_1, construct their blocks, B_0 and B_1, independently and announce them at $t = 0$. Each attestor waits till $t = \tau_1$ and attests to *all* valid blocks received within this duration. Further, each attestor provides a vote indicating the order of block reception. $B_i \prec_j B_{i^+}$ implies that A_j received B_i before B_{i^+}, where $i^+ = 1 - i$. If A_j's attestation on B_{i^+} is missing, we consider $B_i \prec_j B_{i^+}$. If an attestor fails to receive any block within $t = \tau_1$, then it makes an attestation on *empty* similar to Ξ.

Block Selection and Reward Mechanisms. After attestations are aggregated, at most one block is confirmed. Let X_i, Y_i represent the number of attestations and the number of votes received for B_i. Similar to Ξ, for a block to be considered for confirmation, it has to achieve K attestations, i.e., $X_i \geq \mathsf{K}$.

i. $\forall i \in \{0, 1\}$, if $X_i < \mathsf{K}$, then no block is confirmed for that slot
ii. $\exists! i \in \{0, 1\}$ s.t. $X_i \geq \mathsf{K}$, then only B_i is confirmed.
iii. $\forall i \in \{0, 1\}$, if $X_i \geq \mathsf{K}$, then confirm $B_k, k \in_R \{0, 1\}$ and share reward from B_k to each proposer as $R_i = \frac{Y_i}{Y_i + Y_{i^+}}$.

2-Prop allows each proposer to propose exactly one block and each attestor to provide one attestation per block per proposer in a slot. We assume that the blocks are valid for the analysis, and any such violations can be handled as in Ξ. Fig. 1 shows difference between Ξ and 2-Prop.

Latency Game. We model 2-Prop as a 2-player game, which we refer to as *Latency Game*, $\Gamma^{\mathscr{L}} = \langle \mathbf{P}, (S_i)_{i \in \mathbf{P}}, (U_i(\cdot))_{i \in \mathbf{P}} \rangle$, with $\mathbf{P} = \{P_0, P_1\}$. **Strategy space**: P_i's strategy space is the delay $\delta_i \in [0, \tau_1]$ and $U_i(\delta_0, \delta_1)$ is the expected utility when P_0, P_1 delay their block announcement by δ_0, δ_1 respectively. **Utility.** Let $\mathfrak{U}$ denote the expected reward of P^ℓ from transaction fees and MEV accrued from $t = -\tau$ to $t = 0$ (w.r.t. to the start of the slot). Since the block reward is constant, we do not model it in the utility/rewards. Let $v(\delta)$ be a monotonically non-decreasing function that represents the reward earned by delaying the block by δ. Thus, if its block is confirmed, its expected reward is $\mathrm{E}[\mathfrak{U} + v(\delta)]$. To model the valuation of block over time, we analyze the timing information for blocks 21720000-21750648. We observe that $v^l_P(s) = (1 + 0.03\delta)\mathfrak{U}, \forall \delta \in [0, \tau_1]$ and thus, we safely upper-bound it as a linear function:

$$v(\delta) = c \cdot \frac{\mathfrak{U} \cdot \delta}{\tau_1}, \quad c \leq 1 \text{ and } \delta \in [0, \tau_1] \tag{1}$$

Let $q_i(\delta_i)$ be the probability that B_i reaches an attestor within $t = \tau_1$ when P_i delays the block proposal by δ_i. Furthermore, let $p_i(\delta_i, \delta_{i^+})$ be the probability that $B_i \prec_j B_{i^+}$ given P_i, P_{i^+} delay the block proposal by δ_i, δ_{i^+}, respectively. Formally, we have

$$q_i(\delta_i) = \int_0^{\tau_1 - \delta_i} f_{P_i}(x) dx, \quad \hat{q}_i(\delta_i) = 1 - q_i(\delta_i)$$

$$p_i(\delta_i, \delta_{i^+}) = \int_0^{\tau_1 - \delta_i} f_{P_i}(x) \int_{x + \delta_i - \delta_{i^+}}^{\tau_1 - \delta_{i^+}} f_{P_{i^+}}(y) \, dy \, dx$$

With this, we analyze the game mathamtically. More details can be found in the full version [8]. The following are our results.

3 RESULTS

Homogeneous Setting. In homogeneous setting, we have $f_{P_0} = f_{P_1} = f$; hence, $\forall \delta \in [0, \tau_1], q_i(\delta) = q_{i^+}(\delta), p_i(\delta_i, \delta_{i^+}) = p_{i^+}(\delta_i, \delta_{i^+})$.

Theorem 1. *Under homogeneous setting, with support $[0, \tau_1]$ for $f_{P_0}(f_{P_1})$, $(\delta_0^{NE}, \delta_1^{NE}) = (0, 0)$ constitutes a Nash Equilibrium of $\Gamma^{\mathscr{L}} = \langle P, (S_i), (U_i) \rangle$ in 2-Prop is when $c \leq 1$.*

Heterogeneous Setting. Computing the PSNE analytically for general network models in the heterogeneous setting is complex. Hence, we discretize the strategy space and model a Bi-matrix version of $\Gamma^{\mathscr{L}}$ as $\Gamma^{\mathscr{D}} = \langle \mathbf{P}, (S_i^\zeta), (U_i) \rangle$, where $S_i^\zeta = \{0, \zeta, 2\zeta, \ldots, \tau_1\}$, is $\zeta-$discretized strategy space of S_i. We consider a small discretization step $\zeta << \frac{1}{\tau_1}$ for analysis to minimize discretization error. We assume U_i is Lipschitz continuous, and therefore, $\Gamma^{\mathscr{D}}$ well approximates $\Gamma^{\mathscr{L}}$. Empirically, packet delays typically follow a Gamma distribution [4], and hence we assume f_Ps follow the same distribution. For analyzing $\Gamma^{\mathscr{D}}$, we compute the Nash Equilibrium of $\Gamma^{\mathscr{D}}$ under two scenarios D_1, D_2 with different network distributions for P_0, P_1 represented, with slight abuse of notation, by tuple (f_{P_0}, f_{P_1}):

- $D_1 = \{(f_{P_0}, f_{P_1}) : P_0$ is fast, with $\mu_0 \in \{0.075\tau_1, 0.15\tau_1, 0.25\tau_1\}$, and P_1 with $\mu_1 = \gamma\mu_0, \gamma \in \mathbb{R}\}$ for carefully chosen γ values.
- $D_2 = \{(f_{P_0}, f_{P_1}) : P_0$ is slow, with $\mu_0 \in \{0.95\tau_1, \tau_1, 1.05\tau_1\}$ and P_1 with $\mu_1 = \gamma\mu_0, \gamma \in \mathbb{R}\}$ for carefully chosen γ values.

Other Important Results for Latency Games. We generate utility matrices for 75 games in $\Gamma^{\mathscr{D}}$ from both D_1 and D_2 using Ethereum protocol specification [3] i.e., $\tau = 12s$ seconds, $\tau_1 = 4s$, and $n = 127, \mathsf{K} = \lfloor \frac{2n}{3} \rfloor + 1$. From these analyses, we claim the following about the equilibrium delay δ^{NE}. First claim states, a slow proposer will never delay and the second claim states that faster proposer would delay only if the slower proposer is very slow.

Claim 1. *In heterogeneous settings with distributions $(f_{P_0}, f_{P_1}) \in D_1 \cup D_2$, for a proposer P_i with $\mu_i > \mu_{i^+}$, $\delta_i^{NE} = 0$.*

Claim 2. *In heterogeneous settings with distributions $(f_{P_0}, f_{P_1}) \in D_1 \cup D_2$, for a proposer P_i with $\mu_i < \mu_{i^+}$ and $\mu_{i^+} << \tau_1$, $\delta_i^{NE} = 0$.*

4 CONCLUSION

We show that the timing games can be mitigated by inducing competition with just one additional proposer. Under homogeneous settings, we show that an on-time block proposal is the Nash Equilibrium. Under heterogeneous settings, we show that an on-time block proposal is the Nash Equilibrium for the faster proposer, provided the slow proposer is not extremely slow . We believe our analysis provides new insights into modeling consensus protocols by accounting for timing.

REFERENCES

[1] Kefei Cheng, Jiashun Xu, Liang Zhang, ChengXin Xu, and Xiaotong Cui. 2022. Fault Detection Method for Wi-Fi-Based Smart Home Devices. *Wireless communications and mobile computing* 2022, 1 (2022), 4328307.

[2] Kiraly Csaba and Bautista-Gomez Leonardo. 2023. Big Block Diffusion and Organic Big Blocks on Ethereum — blog.codex.storage. https://blog.codex.storage/big-blocks-on-mainnet/. [Accessed 25-09-2025].

[3] Ethereum Foundation. 2023. Ethereum Consensus Specs: Phase 0 – Honest Validator. https://github.com/ethereum/consensus-specs/blob/dev/specs/phase0/validator.md. Accessed: 2025-07-29.

[4] Tong-qiang Guo, Jian-guang Weng, and Yue-ting Zhuang. 2007. Content subscribing mechanism in P2P streaming based on gamma distribution prediction. *Journal of Zhejiang University-SCIENCE A* 8, 12 (Nov. 2007), 1983–1989. https://doi.org/10.1631/jzus.2007.A1983

[5] Khouloud Hwerbi, Ichrak Amdouni, Cédric Adjih, Philippe Jacquet, Leila Azouz Saidane, and Anis Laouiti. 2024. Delay Analysis of the BFT Blockchain Data Dissemination: Case of Narwhal Protocol. In *2024 20th International Conference on Wireless and Mobile Computing, Networking and Communications (WiMob)*. IEEE, Paris, France, 651–656. https://doi.org/10.1109/WiMob61911.2024.10770300

[6] Lucianna Kiffer, Asad Salman, Dave Levin, Alan Mislove, and Cristina Nita-Rotaru. 2021. Under the Hood of the Ethereum Gossip Protocol. In *Financial Cryptography and Data Security: 25th International Conference, FC 2021, Virtual Event, March 1–5, 2021, Revised Selected Papers, Part II*. Springer-Verlag, Berlin, Heidelberg, 437–456. https://doi.org/10.1007/978-3-662-64331-0_23

[7] Lucianna Kiffer, Asad Salman, Dave Levin, Alan Mislove, and Cristina Nita-Rotaru. 2021. Under the Hood of the Ethereum Gossip Protocol. In *Financial Cryptography and Data Security*, Nikita Borisov and Claudia Diaz (Eds.). Springer Berlin Heidelberg, Berlin, Heidelberg, 437–456.

[8] Rasheed M, Parth Desai, and Sujit Gujar. 2026. Let Leaders Play Games: Improving Timing in Leader-based Consensus. arXiv:2602.11147 [cs.GT] https://arxiv.org/abs/2602.11147

[9] Jelena Misic, Vojislav B. Misic, Xiaolin Chang, Saeideh G. Motlagh, and M. Zulfiker Ali. 2019. Block Delivery Time in Bitcoin Distribution Network. In *ICC 2019 - 2019 IEEE International Conference on Communications (ICC)*. IEEE, Online, 1–7. https://doi.org/10.1109/ICC.2019.8761420

[10] Burak Öz, Benjamin Kraner, Nicolò Vallarano, Bingle Stegmann Kruger, Florian Matthes, and Claudio Juan Tessone. 2023. Time Moves Faster When There is Nothing You Anticipate: The Role of Time in MEV Rewards. In *Proceedings of the 2023 Workshop on Decentralized Finance and Security* (Copenhagen, Denmark) *(DeFi '23)*. Association for Computing Machinery, New York, NY, USA, 1–8. https://doi.org/10.1145/3605768.3623563

[11] Toni Wahrstätter. 2025. Timing.pics — timing.pics. https://timing.pics/. [Accessed 16-01-2025].