No Transaction Fees? No Problem! Achieving Fairness in Transaction Fee Mechanism Design

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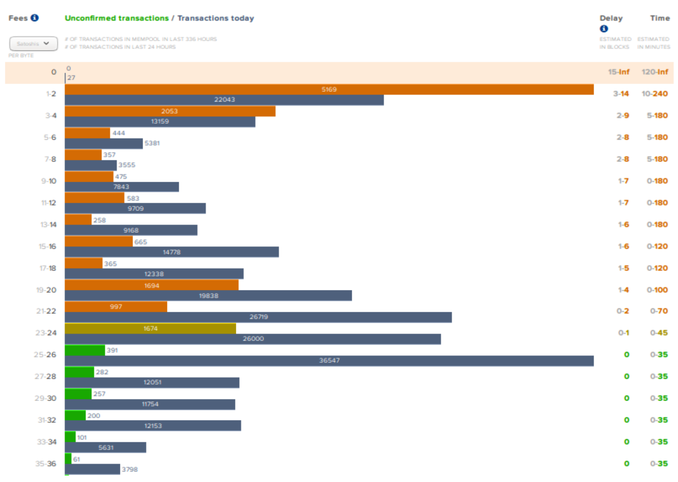
Paper



- Transaction fees in Bitcoin were envisioned to be 'optional'
- In practice, transactions with marginal fee fail to get confirmed
- E.g., Users paying less fees have a waiting time of ≥ 9 blocks, while it is ≥ 14 blocks for those who pay an insignificant amount [4]

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Tiny, cheap-to-deliver payments can open new markets for small digital goods. Can a new wave of crypto-inflected startups plug a longstanding gap in the internet? This piece is part of CoinDesk's Payments Week.

By David Z. Morris · Apr 29, 2022 at 12:15 a.m. · Updated Sep 19, 2023 at 9:33 p.m. · Layer 2

Credit: Coindesk

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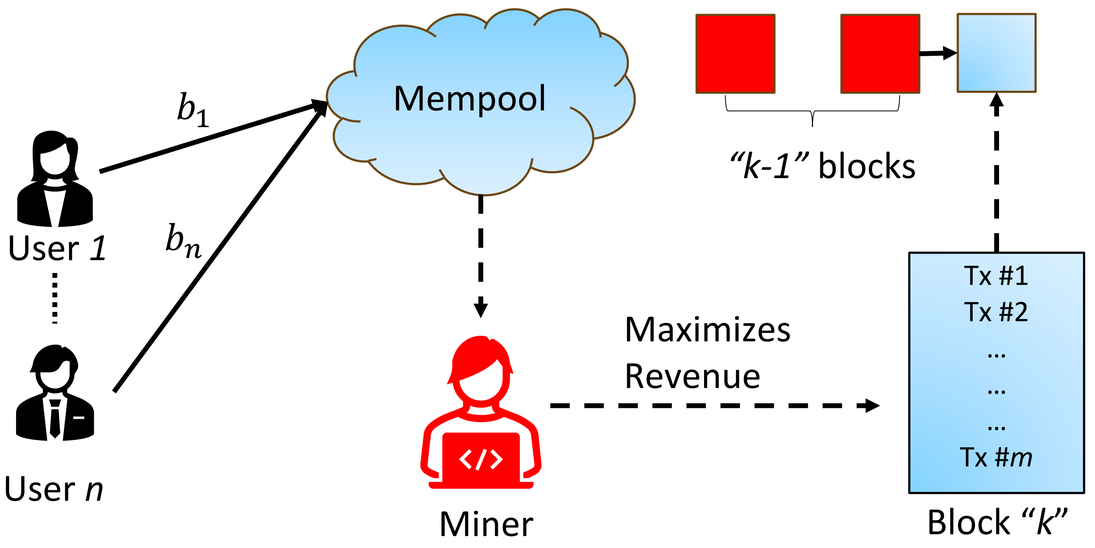


Transaction Fee Mechanisms (TFMs) [1]

Popular TFMs

- First-price Auction (FPA)
- Second-price Auction (SPA
- EIP-1559

Incentive Properties

- User Incentive Compatibility (UIC)
- Miner Incentive Compatibility (MIC)
- Off-chain Collusion Properties

Goal: To design TFMs that are fairer to the transaction creators (or users), while simultaneously preserving the incentive compatibility for both the miner and the users.

Fairness Notions for Transaction Fee Mechanisms

1) Zero-fee Transaction Inclusion (ZTi)
The probability with which a transaction t with transaction fee $b_t = 0$ gets included in a block B_k is strictly non-zero. That is, $\Pr(t \in B_k) > 0$.

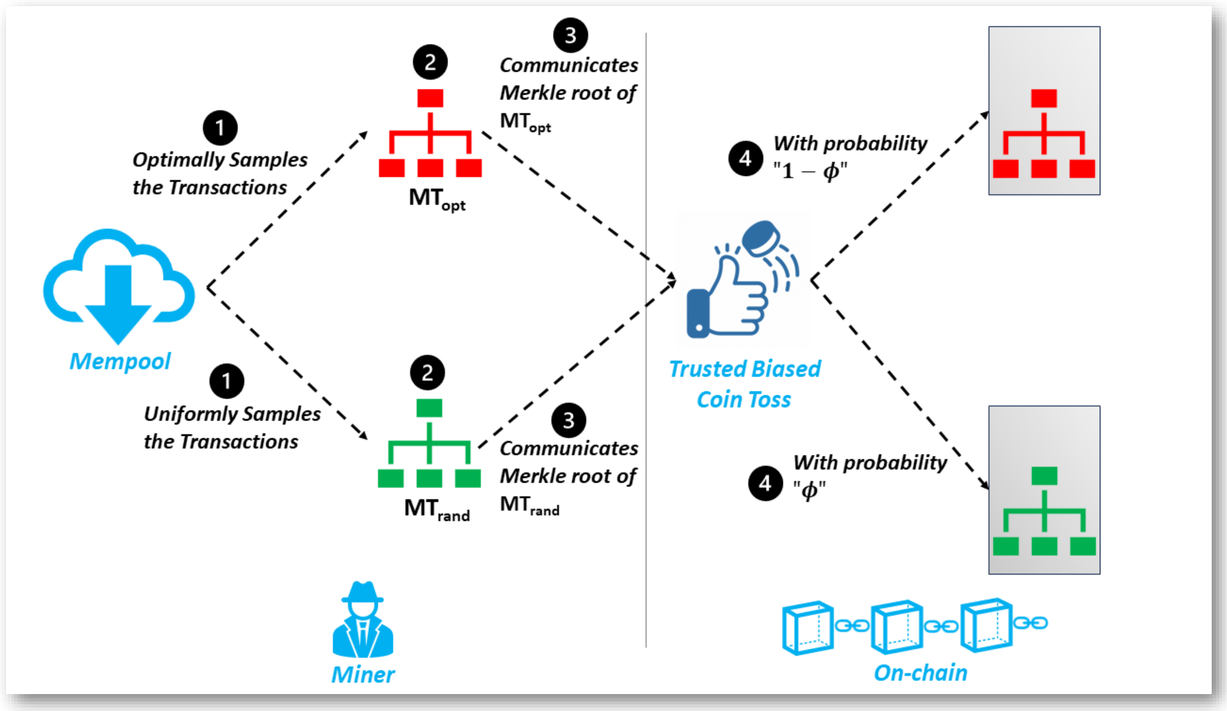
2) Monotonicity
The probability with which a transaction t gets included in a block B_k increases with an increase in its transaction fee b_t, given the remaining bids $\boldsymbol{b_{-t}}$ are fixed. That is, $\Pr(t \in B_k | \boldsymbol{b_{-t}}, b_t + \epsilon) > \Pr(t \in B_k | \boldsymbol{b_{-t}}, b_t)$ for any $\epsilon > 0$ and fixed $\boldsymbol{b_{-t}}$.

A TFM satisfying both our fairness notions ensures that each transaction has a non-zero probability of getting accepted!

Impossibility of Simultaneously Maximizing Miner Utility and Satisfying ZTi

Theorem (Informal). No TFM with a non-trivial payment rule, which provides a strategic miner complete control over the transactions to add to its block, satisfies Zero-fee Transaction Inclusion (ZTi).

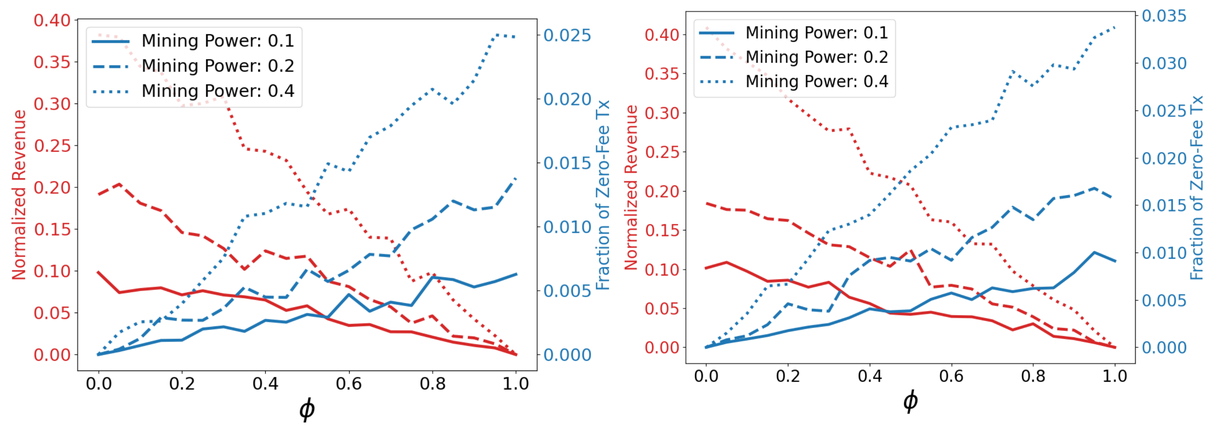
rTFM: Fairness in TFMs using On-chain Randomization



Trusted Biased Coin Toss:

$$O\big(Hash(B_k, \phi)\big) = Hash(B_k) < \phi \cdot TD \; ? \; \mathrm{MT_{rand}} : \mathrm{MT_{opt}}$$

rTFM: Empirical Evaluation



Uniform Bid Distribution | **Exponential Bid Distribution**

Results Summary:

We note that most existing TFMs do not satisfy ZTi. In contrast, rTFM – with an appropriate payment and burning rule – simultaneously satisfies our fairness notions along with UIC and MIC.

★Only if the base fee is "excessively low"

TFM	UIC	MIC	ZTi	Monotonicity
FPA [1]	✗	✓	✗	✓
SPA [1]	✓	✗	✗	✓
EIP-1559 [1]	✓★	✓	✗	✓
BitcoinZF [4]	✓	✗	✓	✓
rTFM + FPA	✗	✓	✓	✓
rTFM + FPA	✓★	✓	✓	✓

Key References

1. Roughgarden (2021). Transaction Fee Mechanism Design. In: EC
2. Chung and Shi (2023). Foundations of transaction fee mechanism design. In: SODA
3. Siddiqui et al. (2020). BitcoinF: Achieving Fairness for Bitcoin in Transaction-Fee-Only Model. In: AAMAS