EC'24 Tutorial on Transaction Fee Mechanism Design

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ACM Conference on Economics & Computation

June 25, 2024

Agenda

- Lecture 1 (20 mins): TFMs for a single block
- **Lecture 2 (20 mins): Dynamics TFMs**
  - Break (30 mins)
- Lecture 3 (20 mins): Extensions to the TFM frameworks
- Panel discussion (30 mins):
  - Mallesh M. Pai (Rice University and Consensys)
  - Tim Roughgarden (Columbia University and a16z crypto)
  - Noam Nisan (Hebrew University of Jerusalem and Starkware)

Why dynamic mechanism?

- **User experience**: users might be willing to wait for future block space

- [**Example**] In each round, a second-price auction allocates a single item for sale.
  - Alice is patient and her value is 6.
  - The first block of the bids is {4, 5}.
    - What should Alice bid?
  - Second block the bids are {1, 2}.
    - If she would be equally happy with waiting for the second block she overpaid by 3.

Related work (more on the tutorial website)

- Dynamical Analysis of the EIP-1559 Ethereum Fee Market, 2021 [S. Leonardos, B. Monnot, D. Reijsbergen, E. Skoulakis, G. Piliouras]
- Dynamic Posted-Price Mechanisms for the Blockchain Transaction-Fee Market, 2021 [M.V.X. Ferreira, D.J. Moroz, D.C. Parkes, M. Stern]
- Dynamic Transaction Fee Mechanism Design, 2024 [M. Pai, M. Resnick]
- Serial Monopoly on Blockchains, 2023 [N. Nisan]
- Competitive Revenue Extraction from Time-Discounted Transactions in the Semi-Myopic Regime, 2024 [Y. Gafni, A. Yaish]

Digital Transaction

- Intermediaries: Visa, Mastercard, Amex, ACH
- Great user experience, but arguably expensive for merchants

$5

$0.10 fee

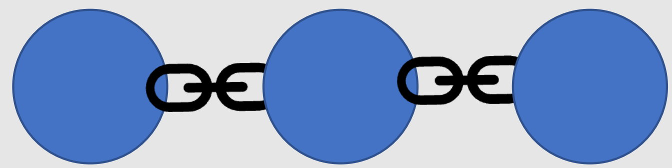
Transaction outcome:

- Rejected (insufficient funds, etc…) or confirmed at $0.10

Digital Transaction on Blockchains

$5

Blockchain



$0.10 fee

Transaction outcome:

- Rejected (insufficient funds, etc…), confirmed at $0.10, or delayed:
  - Either eventually confirmed for $0.10, or
  - It cannot abort and you increase the fee to $0.15 to speed up the confirmation.

Model

- In each round
  - N ``identical'' items for sale
  - A new set of buyers arrive
  - A mechanism allocates the items to at most N buyers
  - Any unallocated buyer stays for the next round (or **timeout**)

Challenge: The mechanism designer has weak commitment power because multiple ``pseudonymous'' miners/sequencers/proposers take turns to implement the allocation rule.

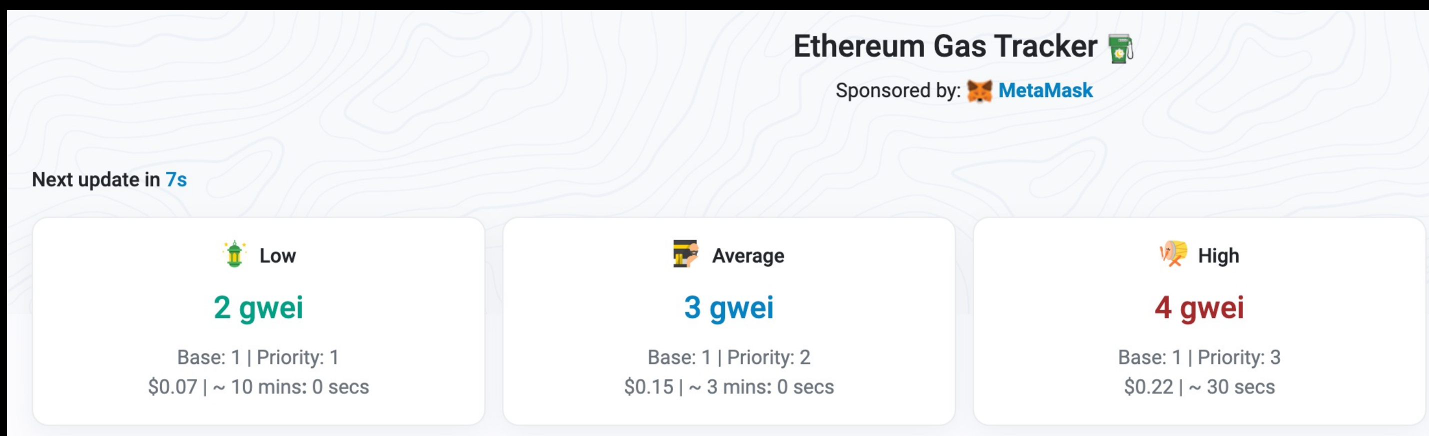
Objective

Maximize Welfare
(i.e., allocate space to who benefits the most)

Simplicity
(e.g., Incentive Compatible)

Posted-price provides simplicity

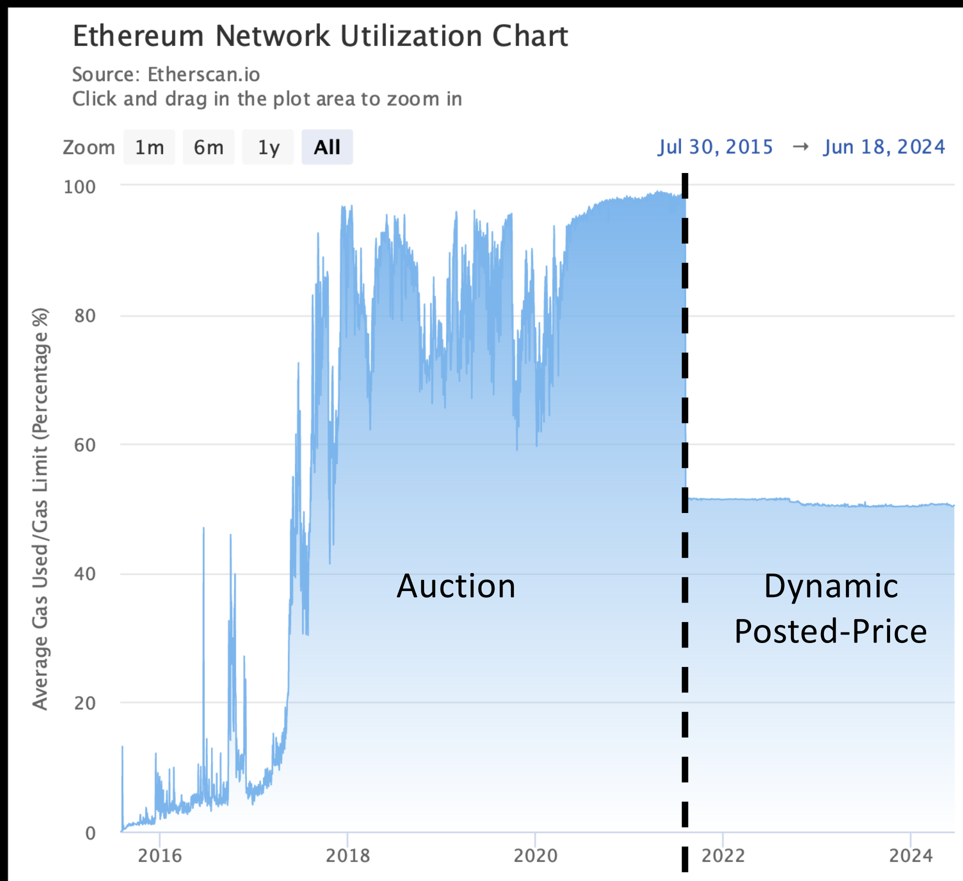
Simplicity …



Source: 3 Gwei | Ethereum Gas Tracker | Etherscan

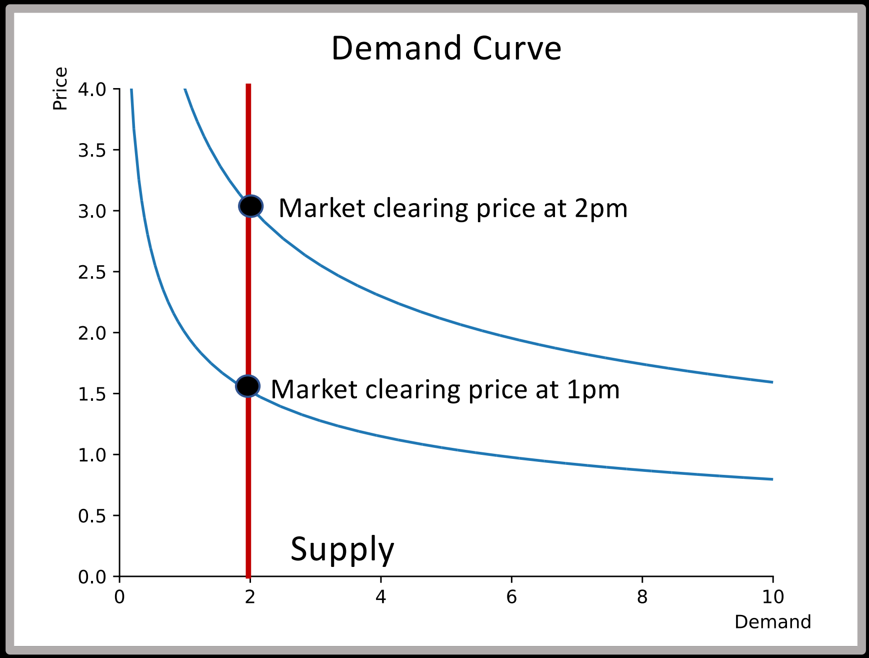
Accessed: 06/19/2024

Welfare



Ethereum Network Utilization Chart
Source: Etherscan.io
Click and drag in the plot area to zoom in
Zoom 1m 6m 1y All
Jul 30, 2015 → Jun 18, 2024
Average Gas Used/Gas Limit (Percentage %)
100
80
60
40
20
0
2016
2018
2020
2022
2024
Auction
Dynamic Posted-Price

How to dynamically price block space given future demand is unknown?



Approach (EIP 1559 [Buterin et al., '19])

1. Each block contains a posted-price: $Price_t$.
2. Miner can **ONLY** include transactions with a bid above $Price_t$.
3. Bidder pays $Price_t$.
4. Compute the posted-price for next block using a pricing rule

Pending Transactions				
TX ID	Sender	Receiver	Value	**Budget**
01	**Alice**	**Bob**	**10**	**1**
02	Charlie	David	15	**0.01**
03	Bob	Charlie	1	**0.5**

Pricing Rules

Utilization-based
(EIP-1559)

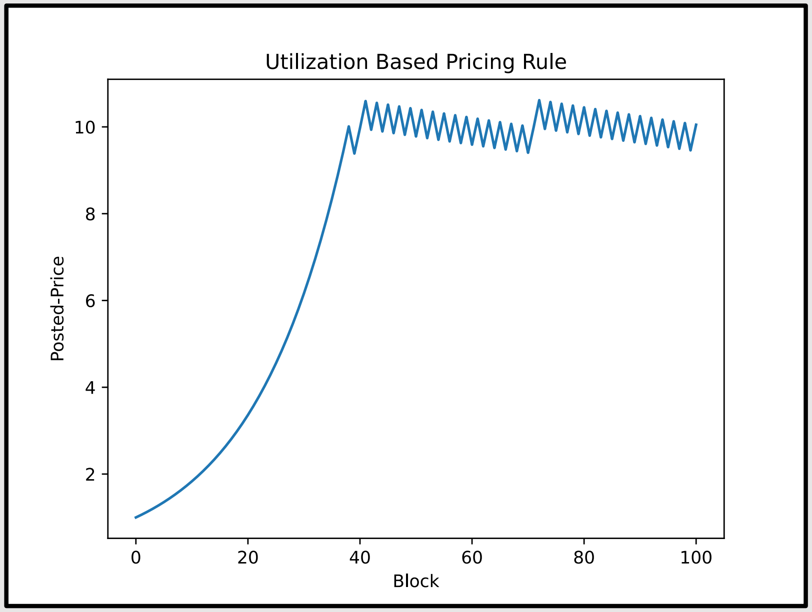
Utilization-based rule

$$Price_{t+1} = Price_t \ (1 + \alpha(Utilization - Target))$$

- Block $\boldsymbol{Utilization} = \frac{\# \ Transactions \ in \ Block}{Block \ Capacity}$.
- **Target** utilization ($Target = $ ½ in EIP-1559).

Instability of utilization-based rule [FMPS '21]

- Suppose 50 slots for sale and 100 users that bid 10.



$$Price_{t+1} = Price_t(1 + \alpha(Utilization - \sout{Target}))$$

= 1/2

$$= Price_t\left(1 \mp \frac{\alpha}{2}\right)$$

Welfare-based pricing rule [FMPS ‘21]

$$\boldsymbol{Welfare}(\boldsymbol{Block}) = \sum_{\boldsymbol{i} \in \boldsymbol{Block}} \boldsymbol{v_i}$$

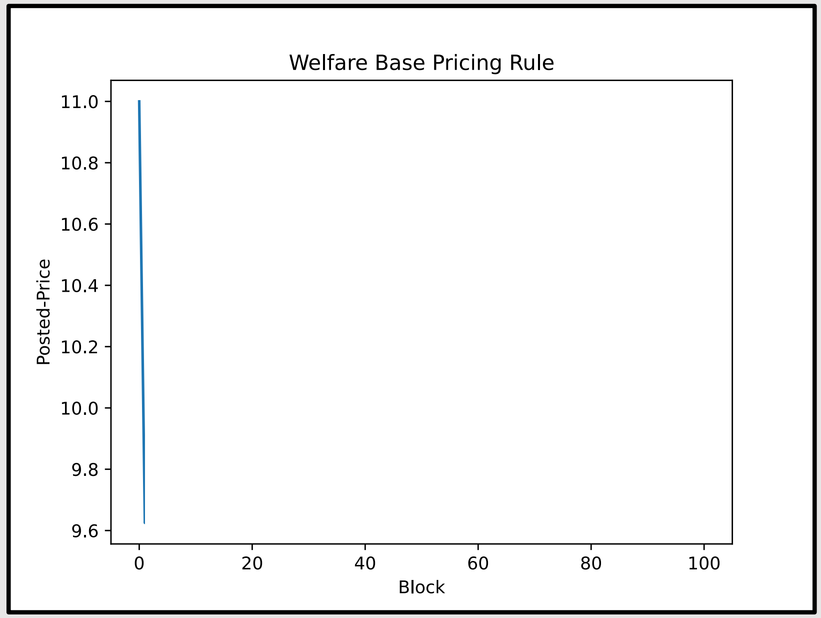
$$\mathrm{P}rice_{t+1} = \alpha \frac{Welfare(Block)}{Capacity} + (1-\alpha)Price_t$$

- Each transaction contributes $\frac{\alpha v_i}{Capacity}$ (where v_i is the bid of bidder i).

Example

- Consider 50 slots for sale and 100 users that bid 10.
- Case 1 ($\mathrm{P}rice_t^W > 10$):

$$\mathrm{Price}_{t+1}^{W} = \alpha \frac{Welfare(Block)}{Capacity} + (1-\alpha)Price_t^W$$
$$= (1-\alpha)Price_t^W$$
$$< \mathrm{Price}_{\mathrm{t}}^{W}$$



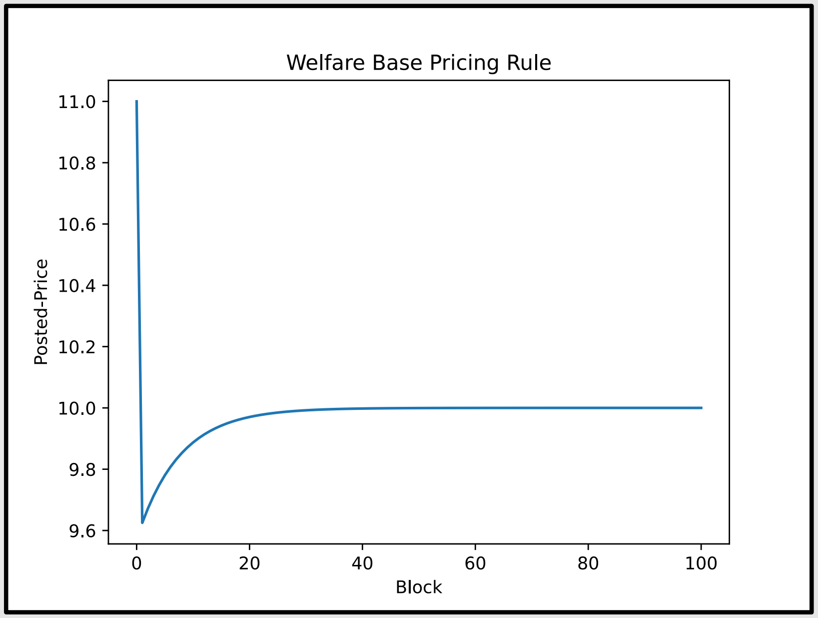
- Then eventually $\mathrm{P}rice_{t+1}^W \leq 10.$

Example: Welfare-based

- Case 2 ($Price_t^W \leq 10$):

$$Price_{t+1}^W = \alpha \frac{Welfare(Block)}{Capacity} + (1-\alpha)Price_t^W$$
$$= 10\alpha + (1-\alpha)Price_t^W$$
$$\geq Price_t^W \text{ and} \leq 10$$

- Thus, sequence of prices o monotone increasing.
- From monotone convergence, posted-price converge.



Why burn the posted-price?

- Without burning
  - If $value \ < \ price$, seller asks buyer to bid $price$
  - If buyer wins, buyer pays $price$ and seller refunds $price - value$
    - Considered undesirable, but it improves welfare
- With burning
  - Seller does not benefit from including buyers with $value \ < \ price$
  - Seller does benefit from deviating when $value \ > \ price$ (e.g, impose a reserve price if they have Bayesian beliefs about values)
    - Example: over 90% of miners deviate from EIP-1559 by selling their block in the MEV-boost.

Opportunities for future work

- What is simplicity for multi-shot mechanisms? (e.g., no regret?)
- AI-assisted tooling (e.g., Ethereum gas tracker)
- In this talk slots are identical. In practice, slots are not identical

Value = (1st slot value, 2nd slot value, …)

  - Result in the posted-price being always smaller than 1st slot clearing price (congested)

- Is Welfare maximization a good objective? What about fairness (MEV)? [Ferreira, Parkes '23]

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Thank you