האוניברסיטה העברית בירושלים
THE HEBREW UNIVERSITY OF JERUSALEM

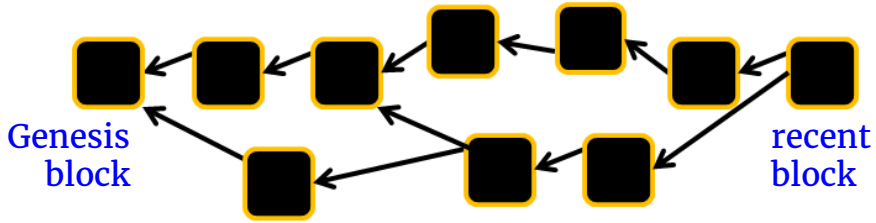
DAGlabs
A novel BlockDAG platform

Incentives and Trade-offs in Transaction Selection in DAG-based Protocols

Yonatan Sompolinsky and Yoad Lewenberg
Scaling Bitcoin, Stanford

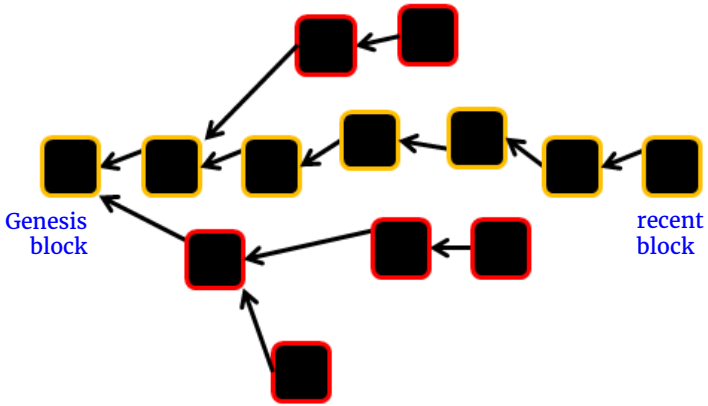
Background

- Directed Acyclic Graph of blocks (blockDAG)
- Inclusive Blockchain Protocols, Financial Crypto ‘15, Lewenberg, Sompolinsky, and Zohar
- Modification and scaling up of Layer 1
- Orthogonal to Layer 2 solutions

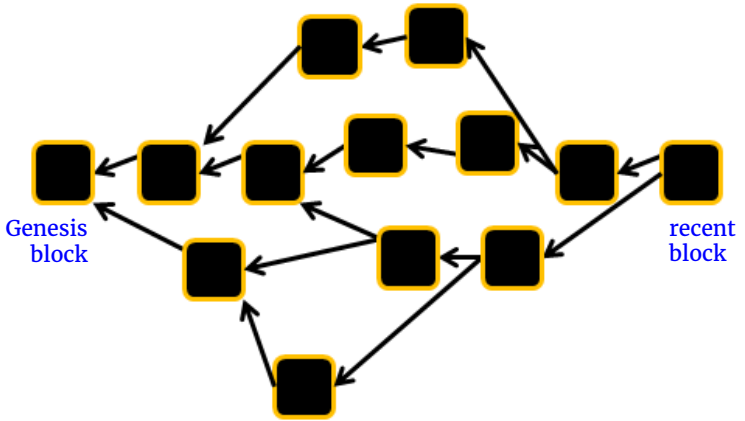


Blockchain vs BlockDAG

Chain paradigm:
1. maintain single chain
2. ignore the rest
3. forks rare



DAG paradigm:
1. maintain entire graph
2. consider all blocks
3. forks common

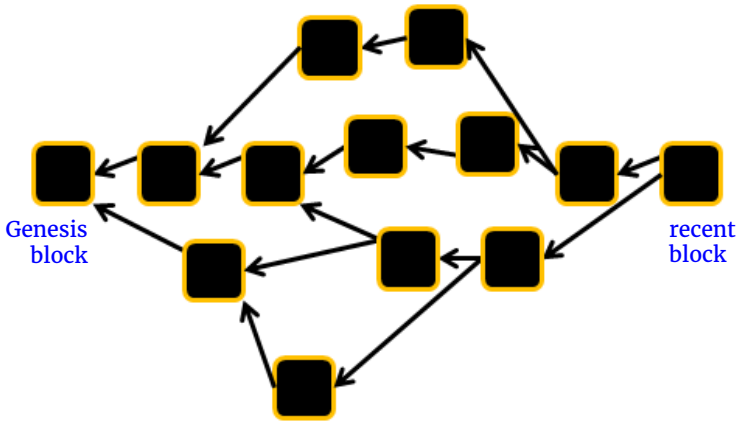


The BlockDAG paradigm

more information **possibly** implies:

- more security
- more scalability
- more fairness

DAG paradigm:
1. maintain entire graph
2. consider all blocks
3. forks common

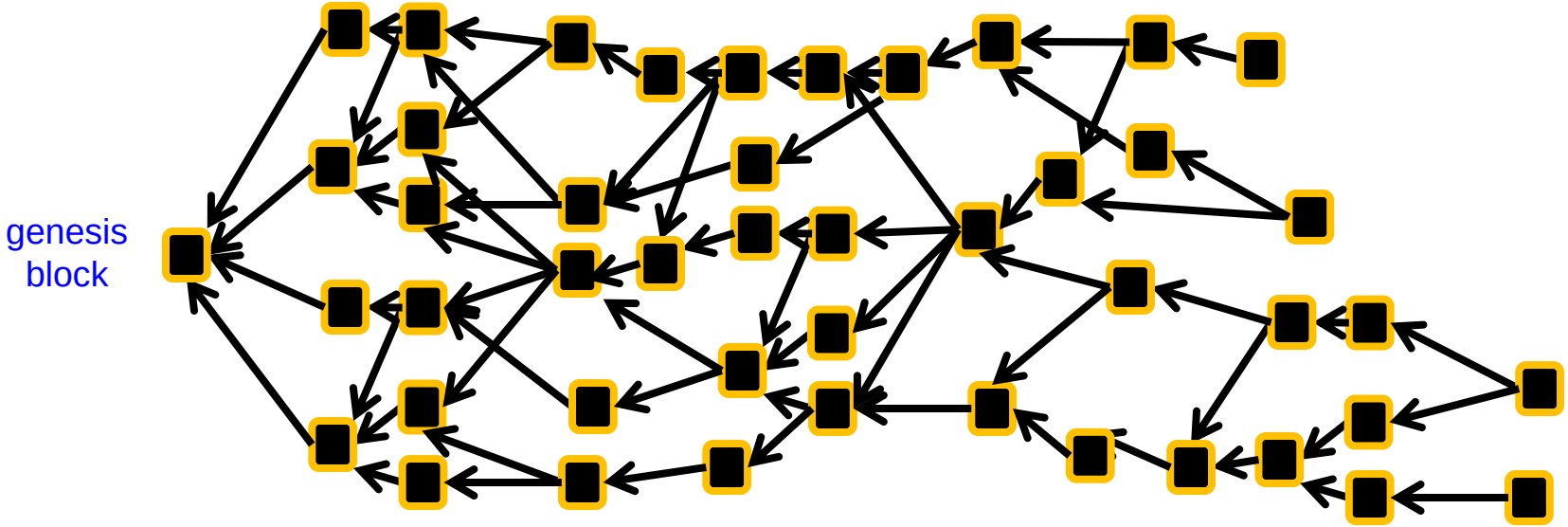


Road to scaling up Layer 1

speed up block rate (or size)

reference all blocks

extract consistency



Road to scaling up Layer 1

speed up block rate (or size)

reference all blocks

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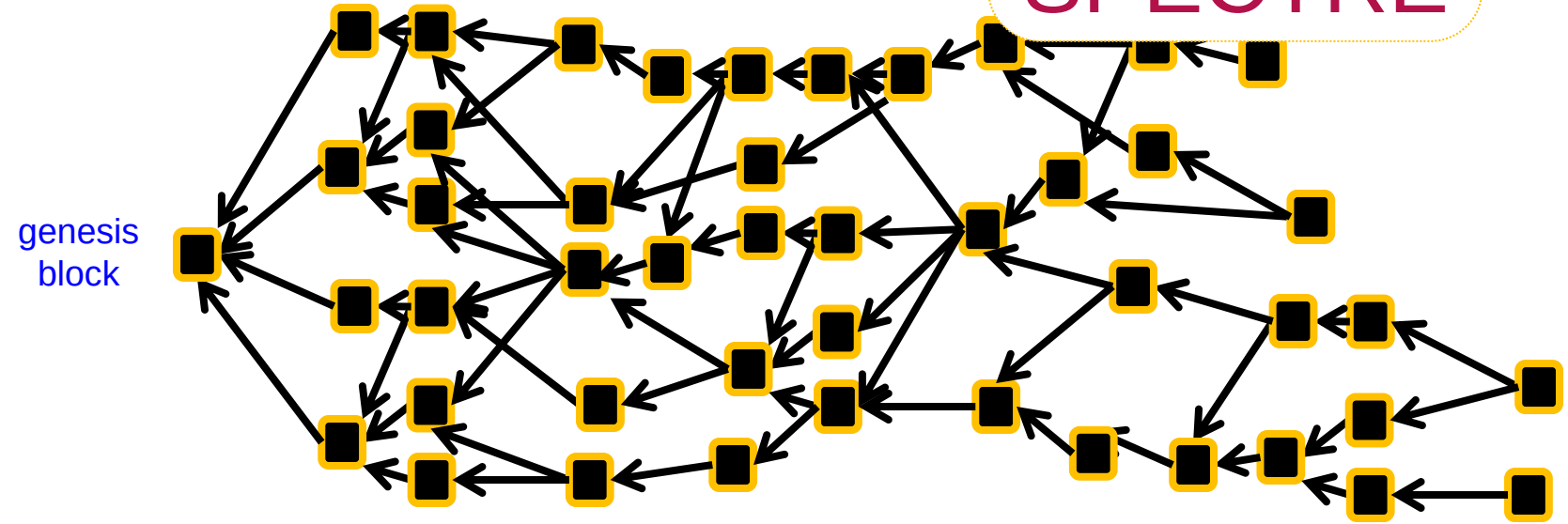
SPECTRE



BlockDAG is (only) a paradigm

- DAG merely a framework, not a solution
- Not all blockDAGs are created equal
- DAG vs chain like highway vs one-lane road…

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Scaling up Layer 1 -- challenges

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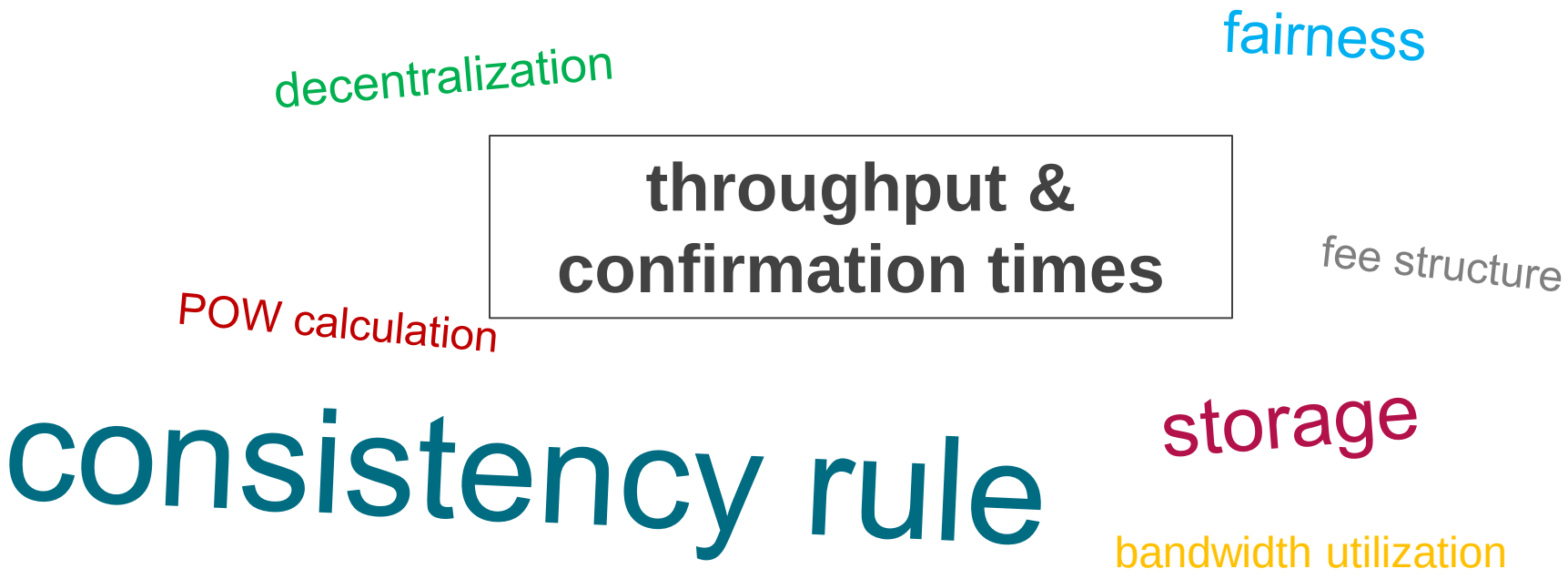
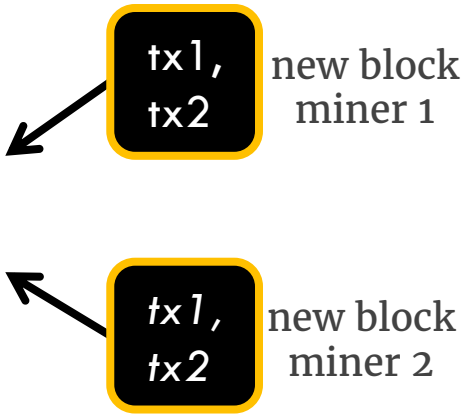


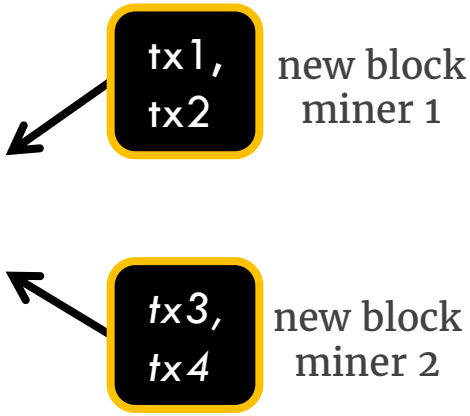
Two scenarios for DAG throughput

mempool: tx1>tx2>tx3>tx4>... (non-conflicting)



tx1,tx2 selected & approved
tx3,tx4 still in mempool

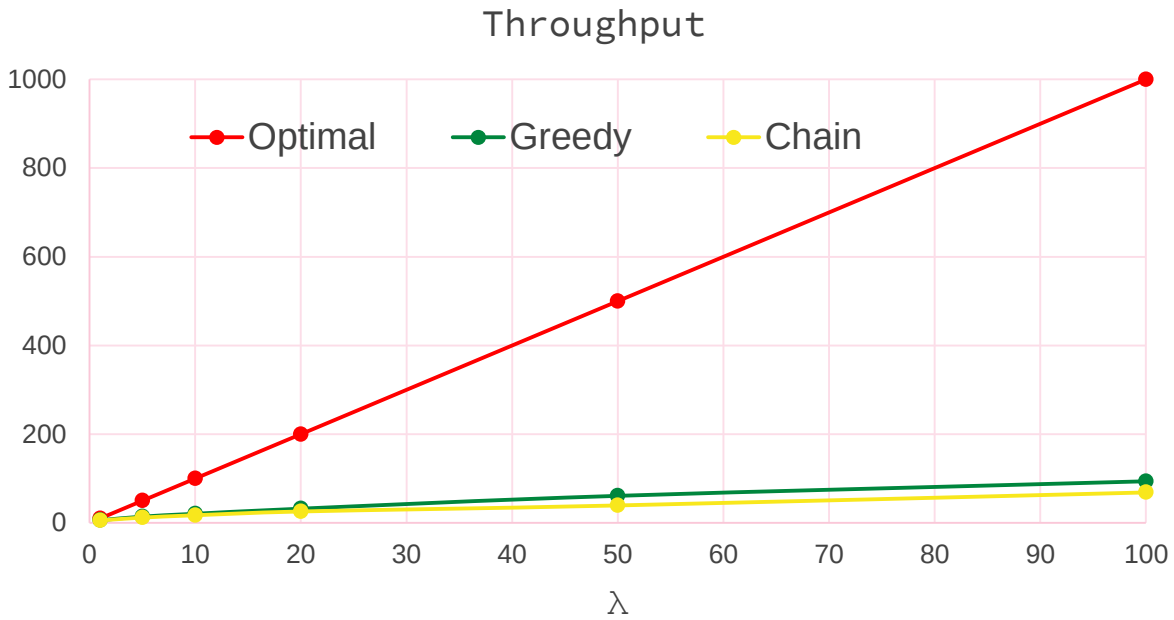
under utilization



tx1,tx2,tx3,tx4 selected & approved
(mempool cleared faster)

full utilization

Proposition 1: under naïve/greedy mining, DAG throughput ≈ chain throughput



Key observation / good news

Miners are incentivized to be avoid selecting the same txns, and to contribute to throughput increase.

Indeed, “collisions” result in loss of fees…

The Inclusive Game

mempool: tx1>tx2
players: miner1, miner2

	miner2 chose tx1	**miner2 chose tx2**
miner1 chose tx1	(0.5*tx1, 0.5*tx1)	(tx1, tx2)
miner1 chose tx2	(tx2, tx1)	(0.5*tx2, 0.5*tx2)

collision on tx1

collision on tx2

The Inclusive Game

pure strategy: select a txn

mixed strategy: select a txn using randomness

	miner2 chose tx1	**miner2 chose tx2**
miner1 chose tx1	(0.5*tx1, 0.5*tx1)	(tx1, tx2)
miner1 chose tx2	(tx2, tx1)	(0.5*tx2, 0.5*tx2)

collision on tx1

collision on tx2

How to “solve” the game

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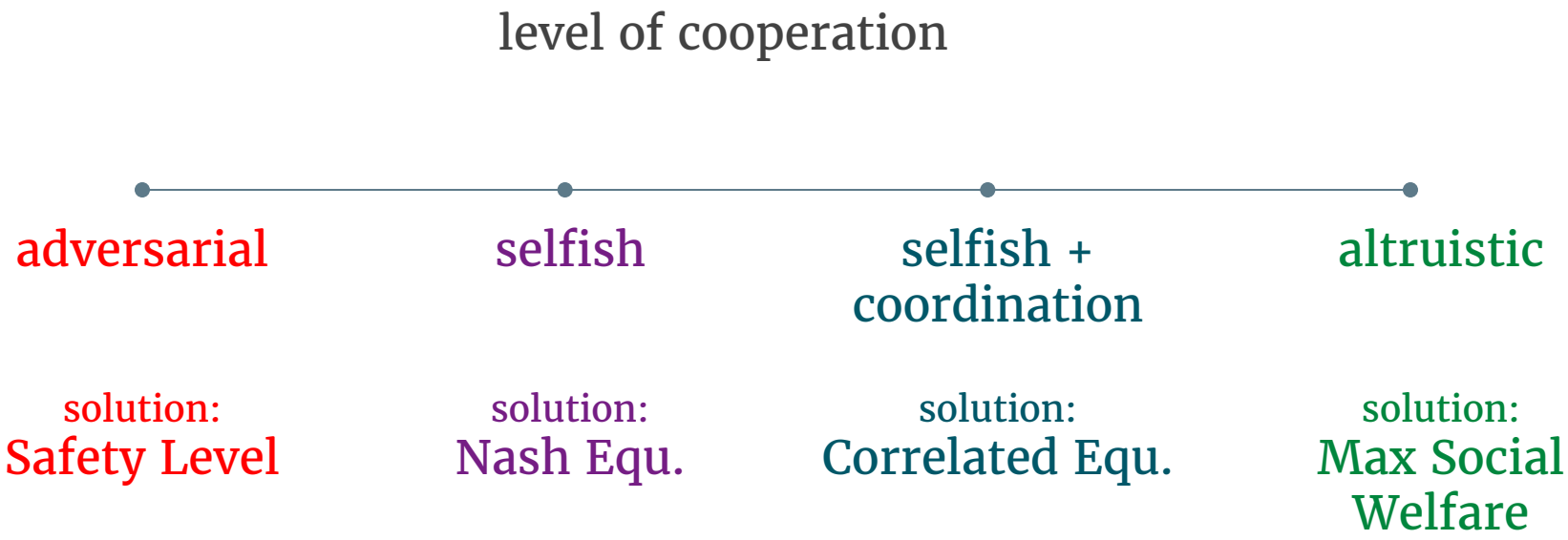
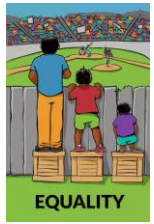
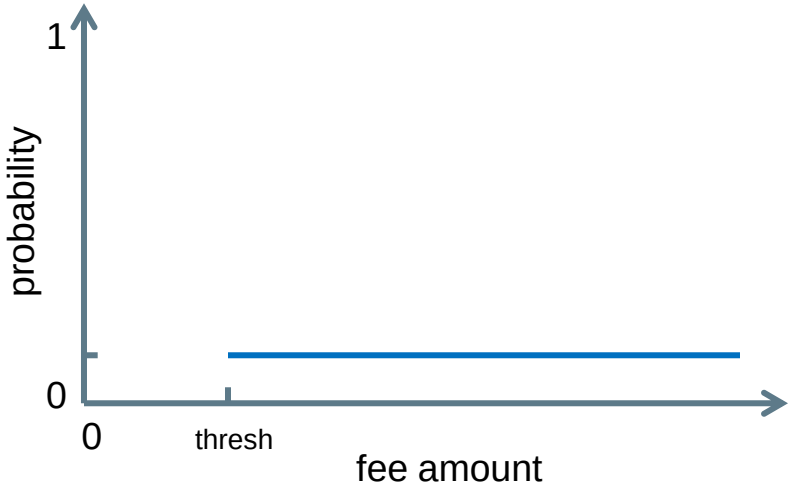


Max Social Welfare

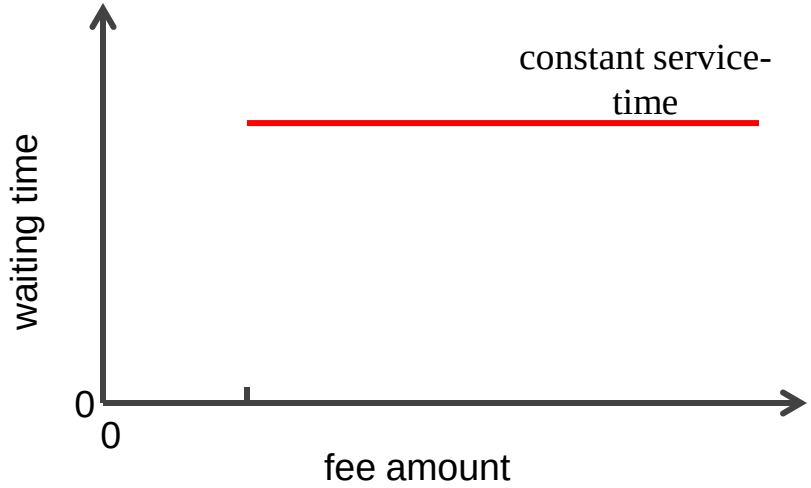
- Solution: select txns uniformly [above capacity threshold]
- No collisions, full utilization
- But there's a catch…





High throughput is not enough

1. Strategically unstable
2. Forces egalitarian waiting times, no QoS levels and preferential treatment



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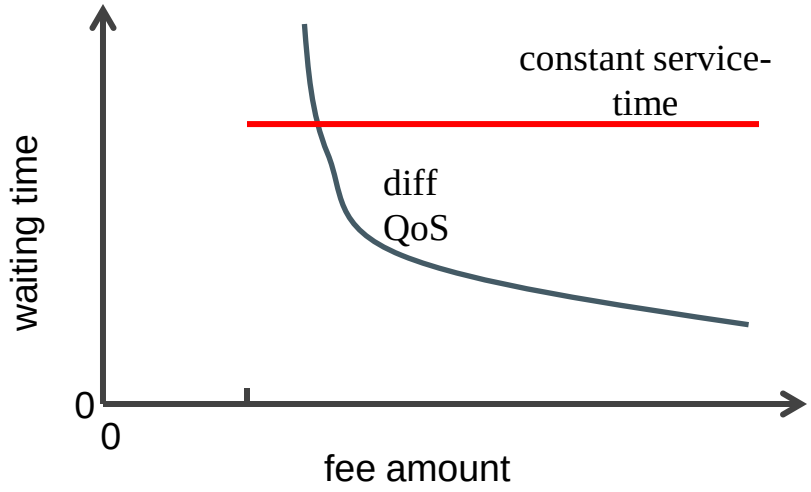

Trade-off: high utilization vs fast conf. times

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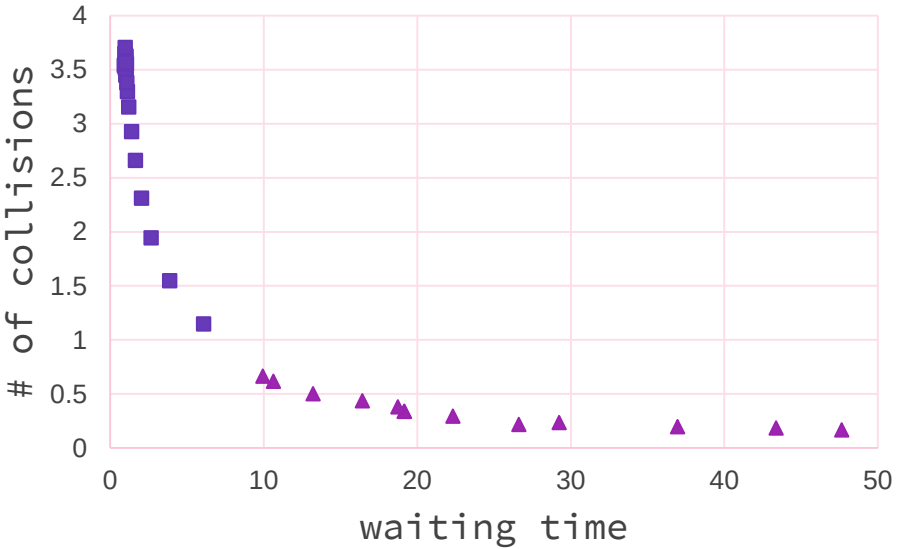
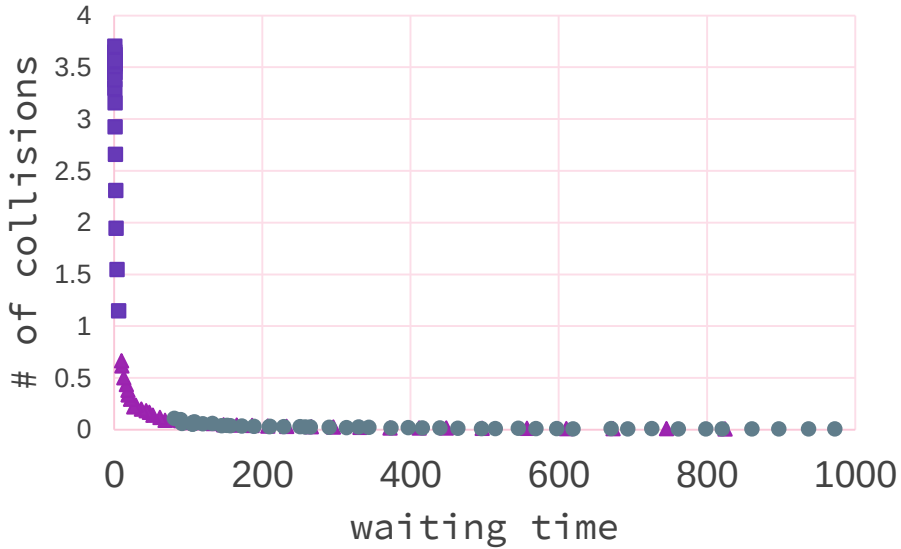
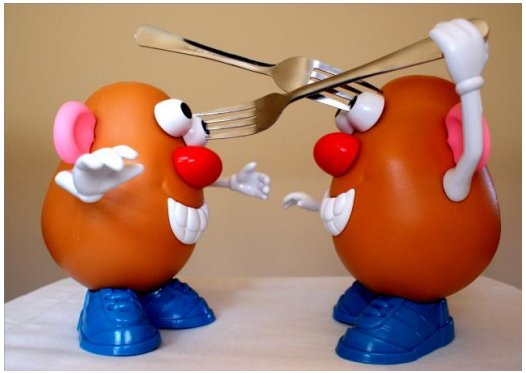
shorter waiting times → more collisions → lower utilization





Nash Equilibrium

- Finding Nash usually hard
- Tit-for-tat strategies
- Greedy pools/miners will suffer retaliation (?)



round #1

miner1\miner2	tx1	tx2
tx1	(0.5*tx1, 0.5*tx1)	(tx1, tx2)
tx2	(tx2, tx1)	(0.5*tx2, 0.5*tx2)

round #2

miner1\miner2	tx1	tx2
tx1	(0.5*tx1, 0.5*tx1)	(tx1, tx2)
tx2	(tx2, tx1)	(0.5*tx2, 0.5*tx2)

round #3

miner1\miner2	tx1	tx2
tx1	(0.5*tx1, 0.5*tx1)	(tx1, tx2)
tx2	(tx2, tx1)	(0.5*tx2, 0.5*tx2)

Nash Equilibrium (myopic)

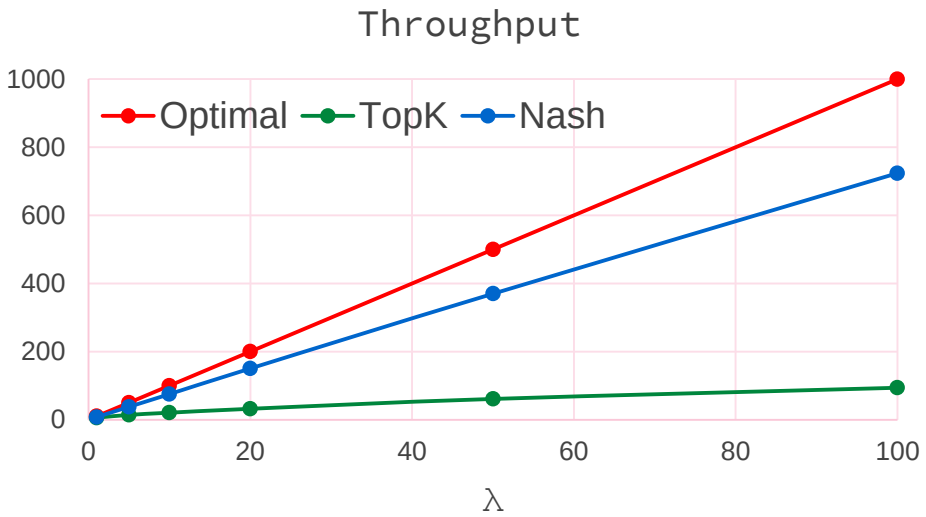
- Assigns high probability to high paying txns
- Not too greedy: top txns not necessarily selected

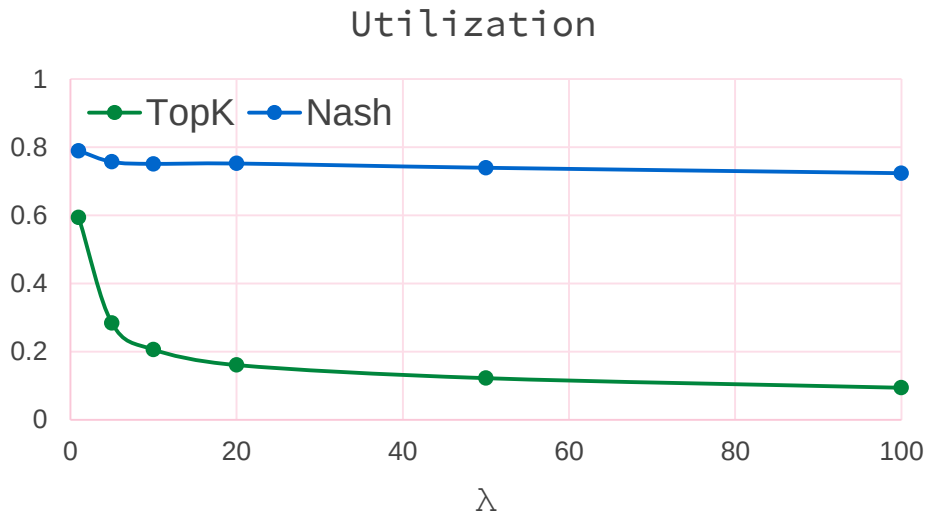
Theorem 6. *Suppose the memory buffer consists of k_l transactions with fee v_l $(1 \le l \le n)$. Denote the individual transactions by $w_1, \ldots, w_m$, which are sorted in descending order of their fees. Denote the index of $v(w_i)$ by $l(w_i)$. The marginal probability $p_i := \frac{q_{l(w_i)}}{k_{l(w_i)}}$ $(1 \le i \le m)$ defines a symmetric equilibrium in the single-shot inclusive-F game, where:*

- $q_l = \begin{cases} k_l \cdot \min\left(f^{-1}\left(\frac{c_{k_{max}}}{v_l}\right), 1\right) & 1 \le l \le k_{max} \\ 0 & k_{max} < l \le n \end{cases}$
- $\forall\, 1 \le l \le n$: $G_l(z) := \sum_{h=1}^{l} k_h \cdot \min\left(f^{-1}\left(\frac{z}{v_h}\right), 1\right) - b$
- $k_{max} := \max\{k \le n \mid \forall l \le k : G_l(v_l) \le 0\}$
- $c_{k_{max}}$ *is the root of* $G_{k_{max}}$.

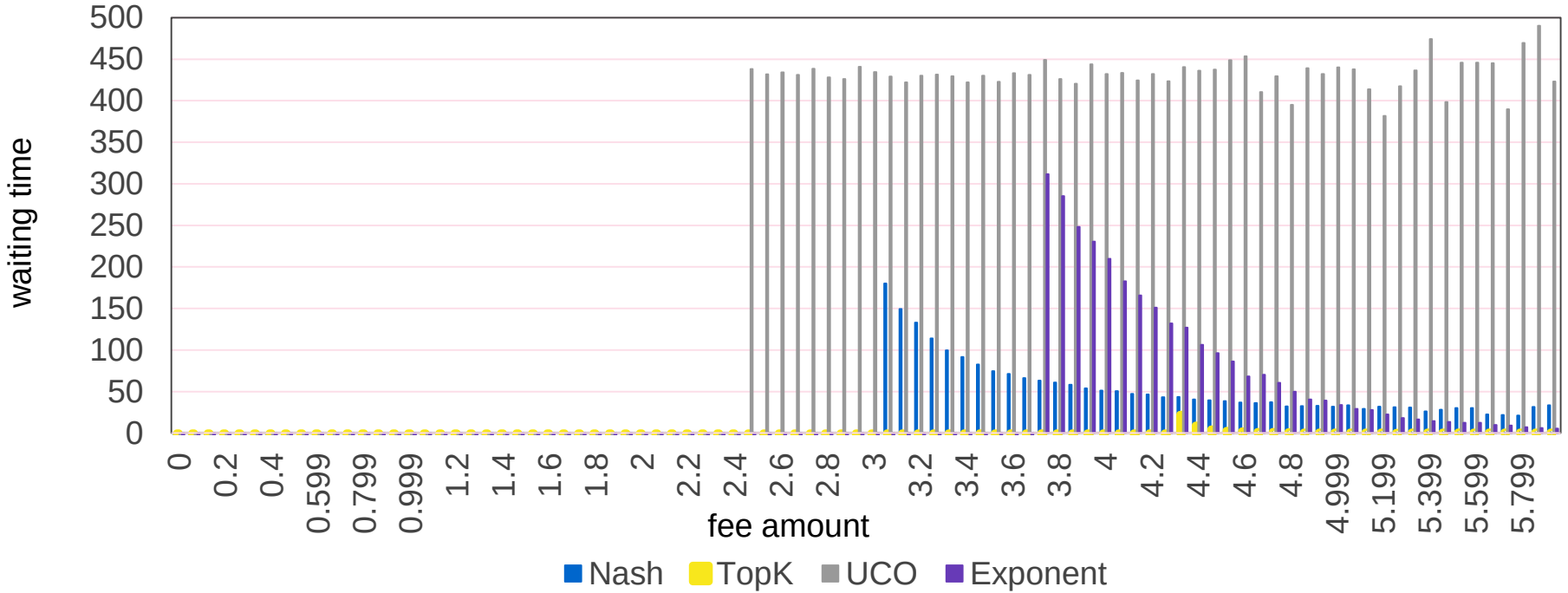
Throughput under Nash

Throughput of: DAG + greedy mining (green)
DAG + Nash Equ. (blue)
DAG + optimal utilization (red)





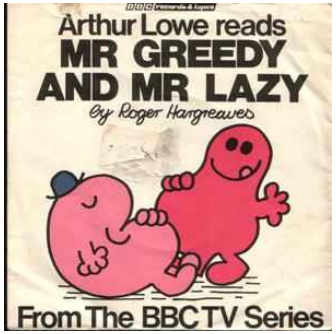
QoS levels


waiting time
500
450
400
350
300
250
200
150
100
50
0
0
0.2
0.4
0.599
0.799
0.999
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
3.2
3.4
3.6
3.8
4
4.2
4.4
4.6
4.8
4.999
5.199
5.399
5.599
5.799
fee amount
Nash
TopK
UCO
Exponent

Correlated Equilibrium / asymmetric Nash

- Can we do better by somehow coordinating between miners?
- Preliminary results: yes, higher throughput
- Coordination mechanism: using prvs blocks’ randomness
- Future work

Scaling and incentives



- Strategic mining in Bitcoin -- sophisticated, risky
  in DAG -- easy (but also marginal)
- Decisions more granular: *which txns to select?*
  how fast to release blocks?
- “Lazy” selfish mining -- miner is lazy in information sharing, does not contribute reasonable bandwidth

When implementing BlockDAG protocols -- incentives *really* matter

“Bitcoiners of the world, unite!
You have nothing to lose but your chains!“