Analysis of the confirmation time in PoW blockchains

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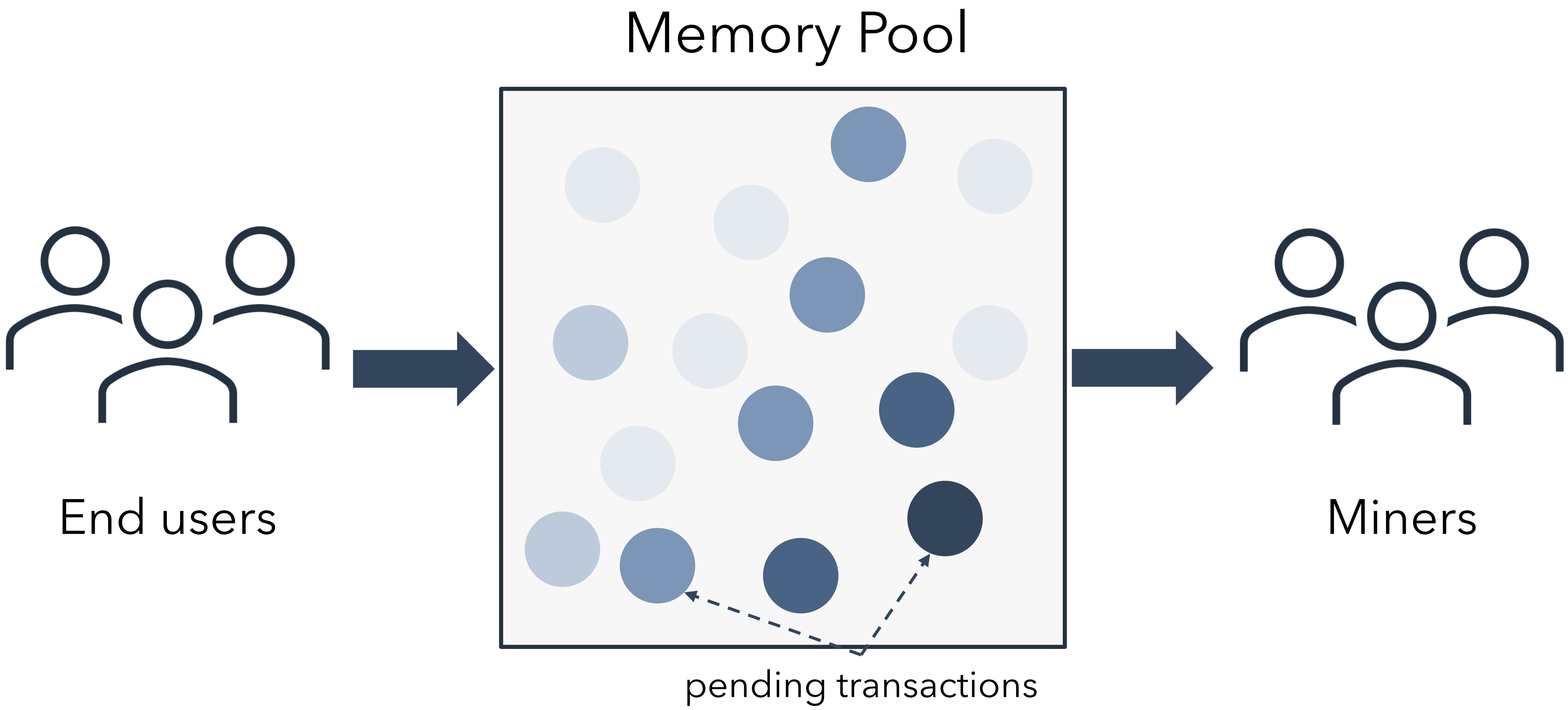
Context: Transaction flow

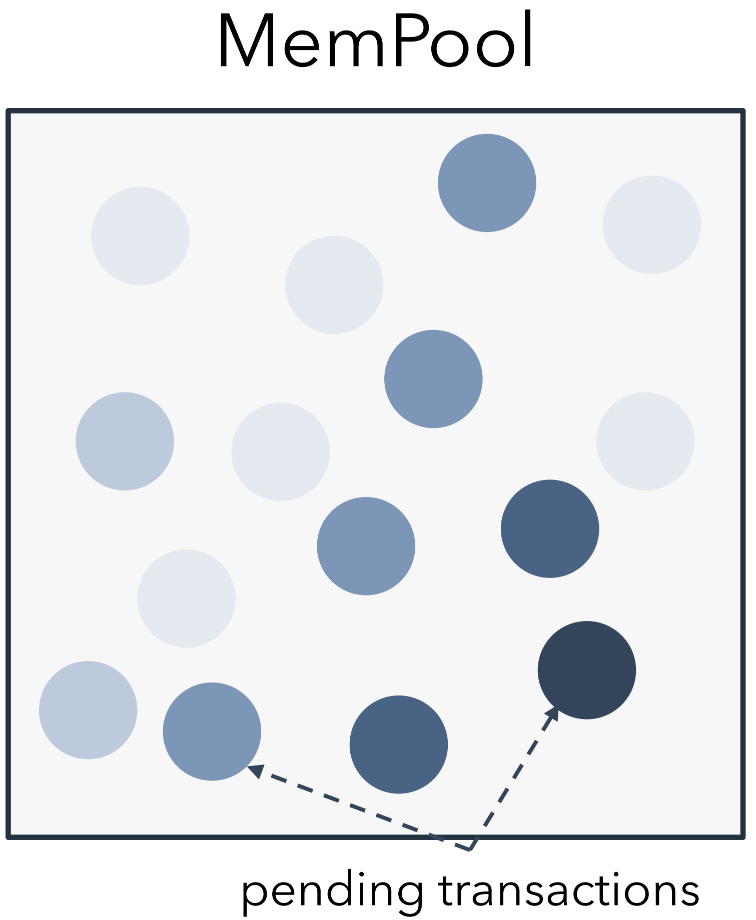


Context: Miner's incentive

Miner's reward is guaranteed:

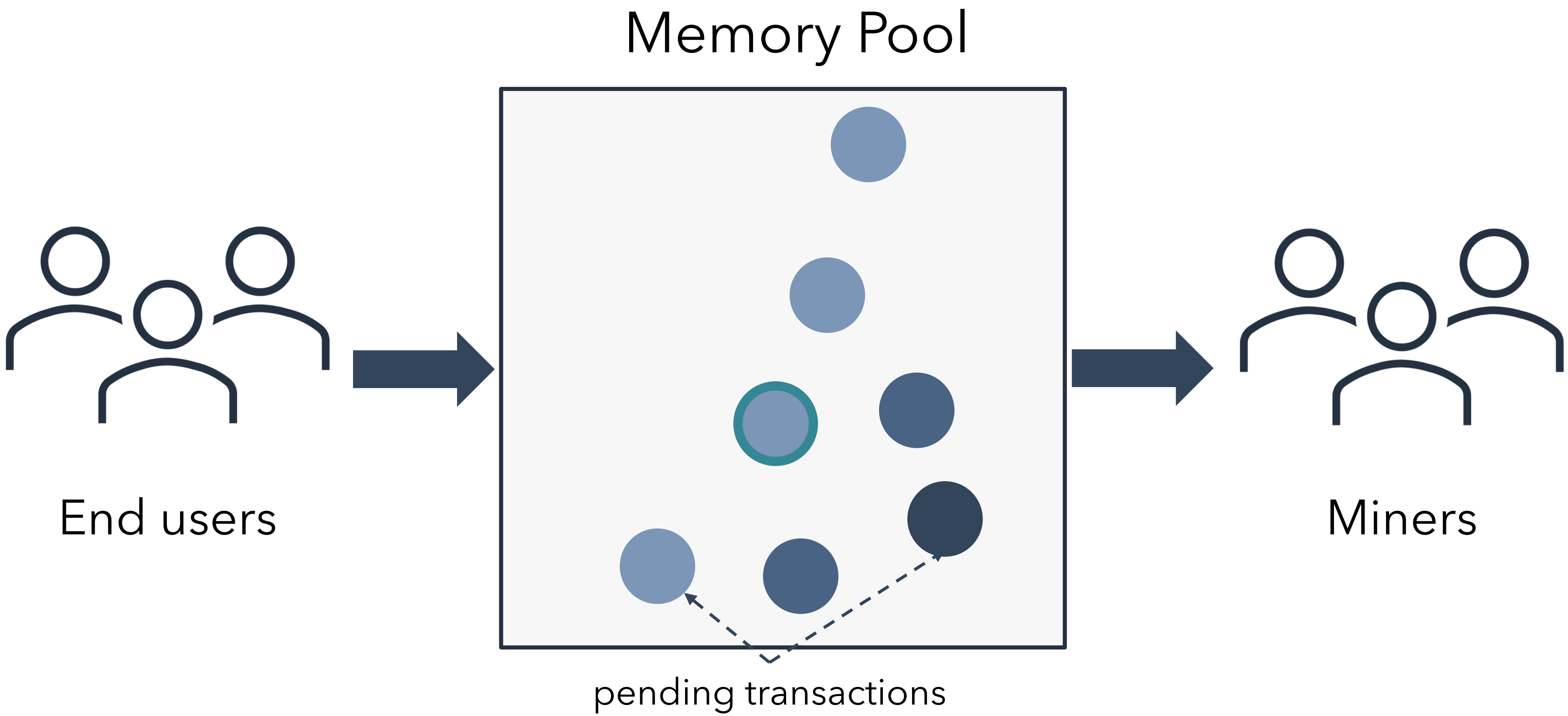
- For each confirmed block
- For each transaction in this block

Miners select the transactions with highest fee*



* Fee per each byte of a transaction size

Transaction flow



Context: Trade-off

End users

Amount of transaction fee

VS

Transaction confirmation delay

Problem statement

Investigate the relationship between offered fee and confirmation delay of transactions in PoW blockchain

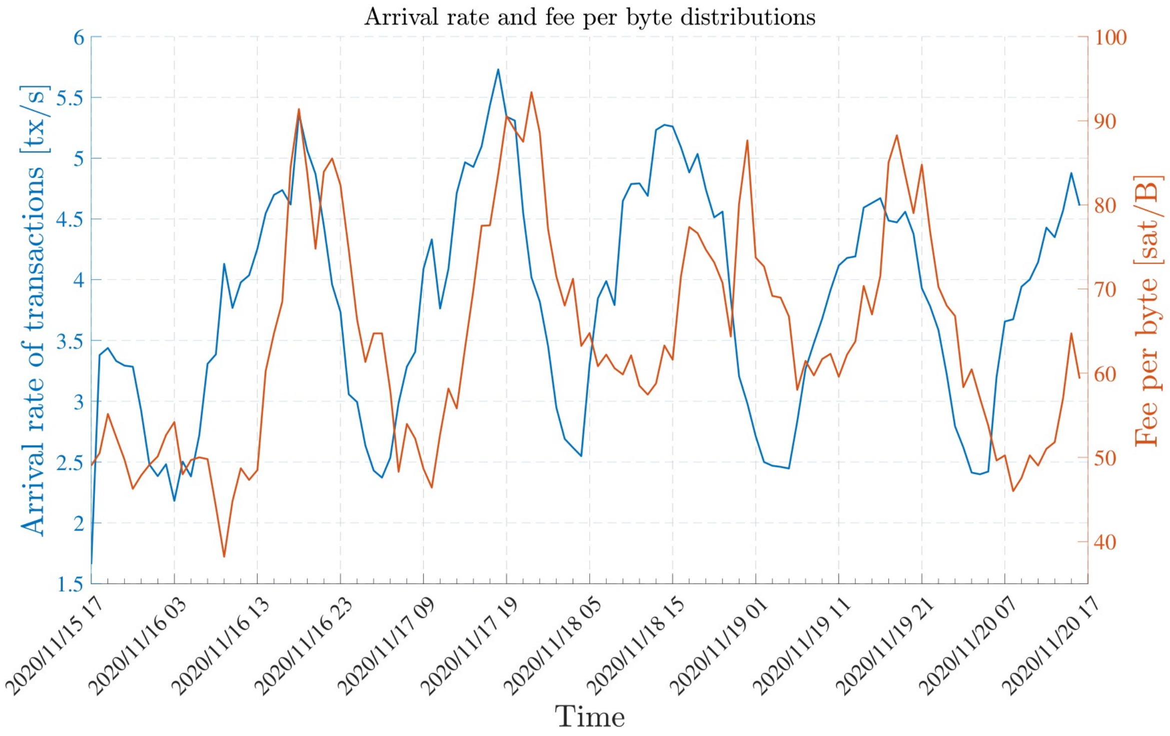
State of the art

Fee determination methods:

Monte Carlo simulations

History-based approaches ('estimatesmartfee', BTC built-in function)

and others



Reactive nature of fee per byte and transaction arrival rate

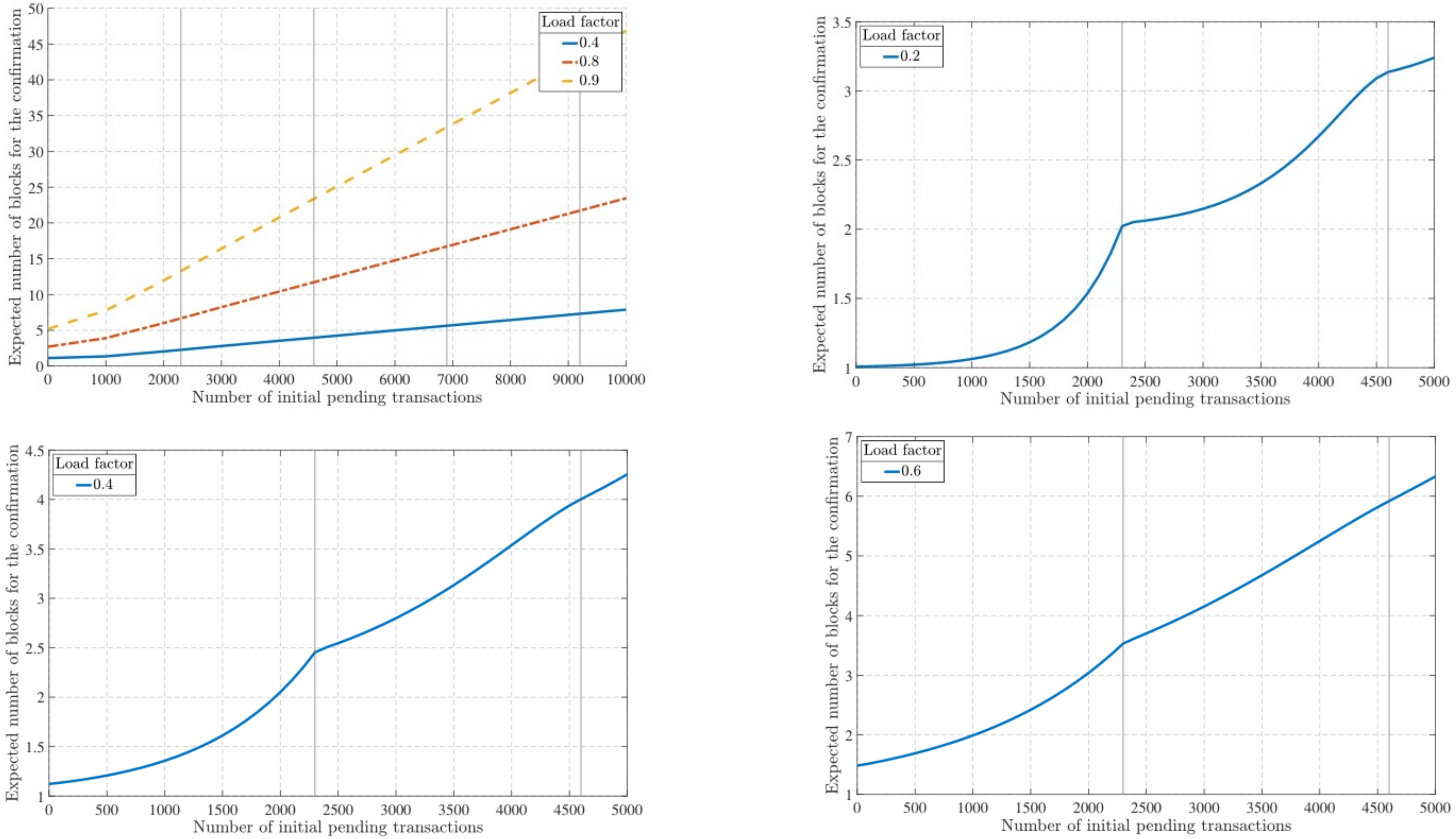
Analytical model

M/M^B/1 queueing system (B – batch/block size) considering:

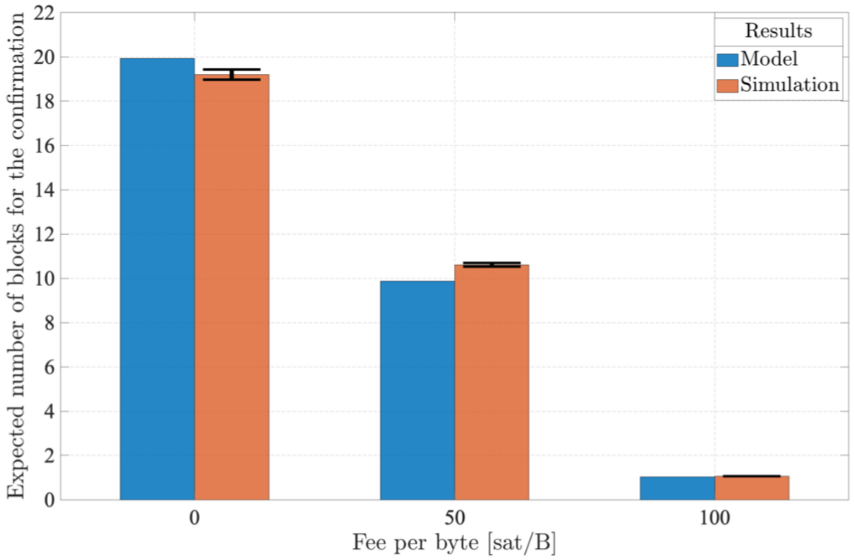
- Offered fee of target transaction
- Transaction arrival rate
- Mempool occupancy
- Fee distribution by other end users

Numerical results

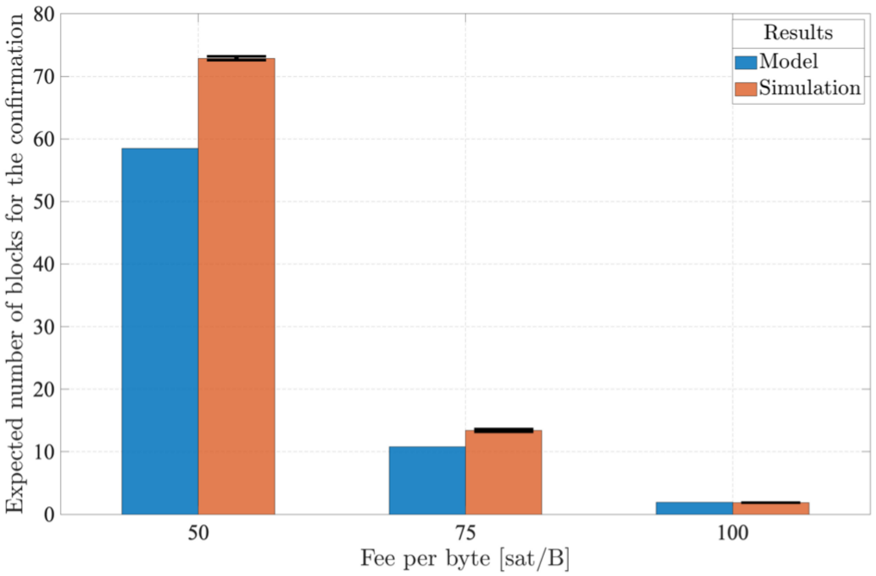
Impact of the initial Mempool occupancy on the expected confirmation time



Validation:model VS simulation



Expected confirmation time (in blocks) as function of fee per byte for model and simulation results, Y=6,000, λ =3.21 tx/s



Expected confirmation time (in blocks) as function of fee per byte for model and simulation results, Y=12,000, λ =4.02 tx/s

Conclusion

- Introduction of $M/M^B/1$ queueing model for confirmation time estimation based on:
  - Transaction offered fee
  - Mempool occupancy
  - Transaction fee destribution in Mempool
  - Transaction arrival rate

Thank you!

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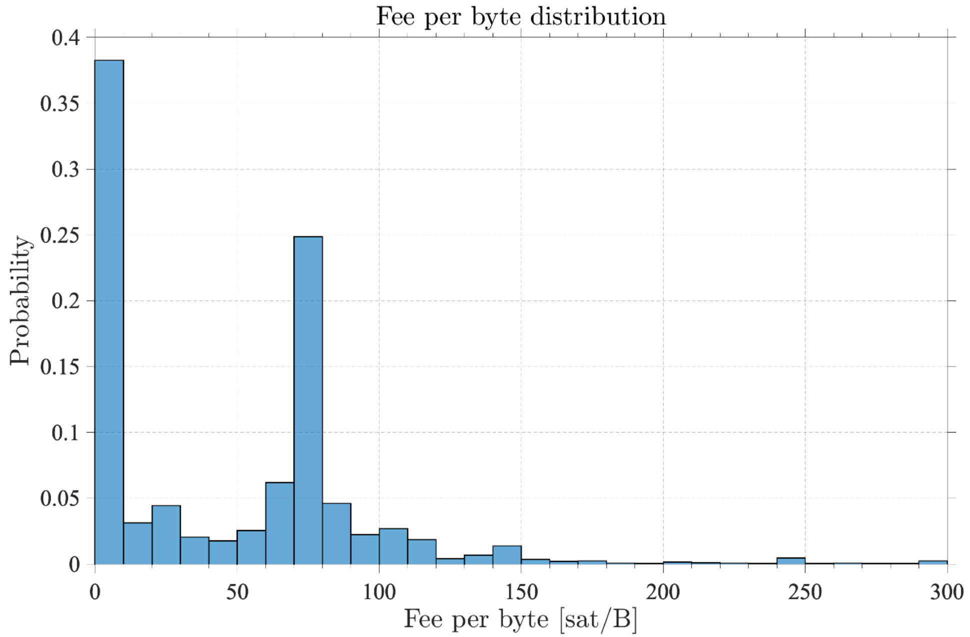
Data

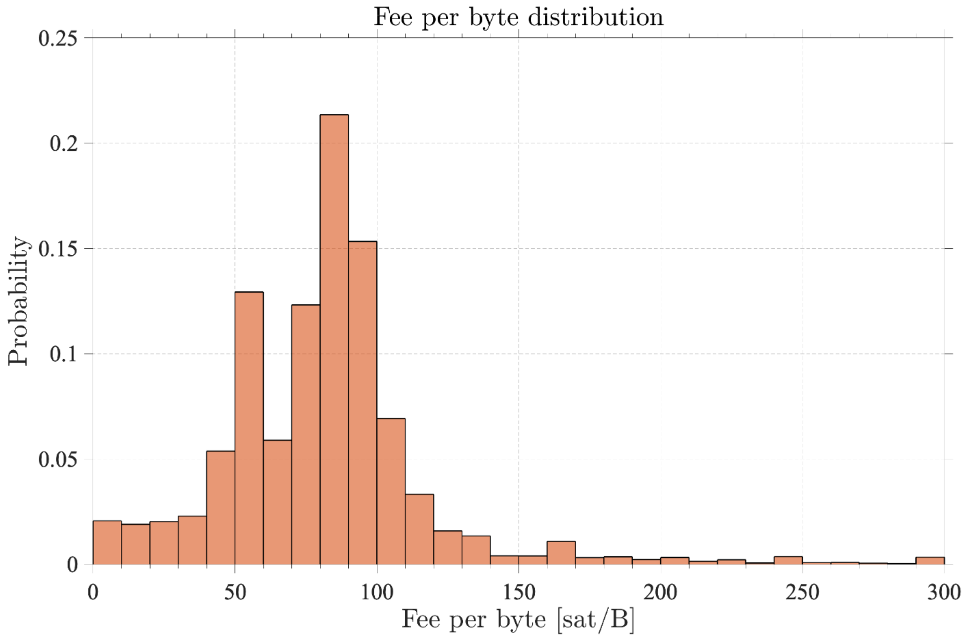
We have collected:

- over 1.5 million of pending TXs
- for 5 days (15/11/2020– 20/11/2020)

Fee per byte distributions



Empirical probability density function in moderate workload conditions



Empirical probability density function in heavy workload conditions

Main theorem

- M_1^Y – expected number of blocks for the transaction validation
- Y - Mempool occupancy* in transactions
- $P_1'(1)$ – constant determined with a numerical procedure
- B – block occupancy
- $\alpha \triangleq \lambda/(\lambda+\mu)$ and
- $\beta \triangleq 1-\alpha$

$$\begin{cases} M_1^1 = P_1'(1) \\ M_1^{Y+1} = M_1^Y + \frac{T_{Y-1}}{\alpha^{Y-1}}\left(M_1^1 + \frac{\beta}{\alpha}\right) - \frac{T_Y}{\alpha^Y} M_1^1 \,, \end{cases}$$

where:

$$T_Y \triangleq \sum_{c=0}^{\lfloor \frac{Y}{B+1} \rfloor} (-1)^{c+1} \binom{Y-Bc}{c} \alpha^{Bc} \beta^c \,.$$

Accuracy validation

Empirical probability density function of relative error of actual and predicted confirmation delays.