HOW TO CHARGE LIGHTNING

The Economics of Bitcoin Transaction Channels

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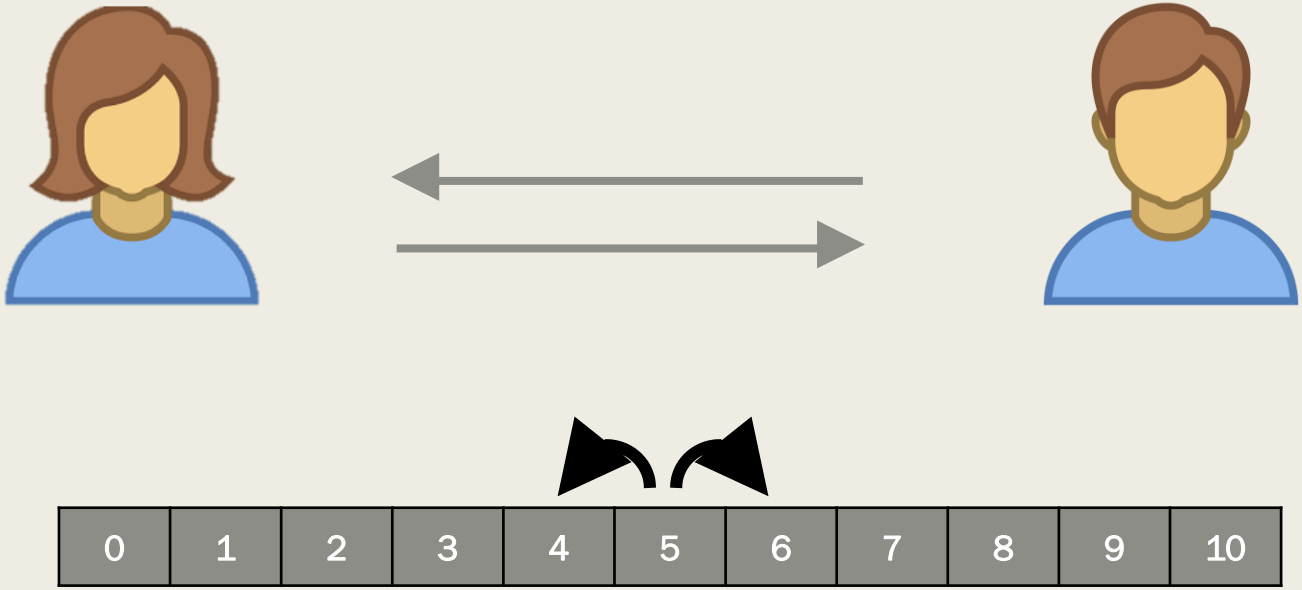
Goals

We want to understand

- How to manage payment channel networks
  - *(channel funding, when to reset them, etc.)*
- The effect of channels on the economics of Bitcoin
  - *on-chain & off-chain volume and fees*

We lack data. Requires lots of assumptions on transaction size distributions, usage patterns.

Managing a single channel



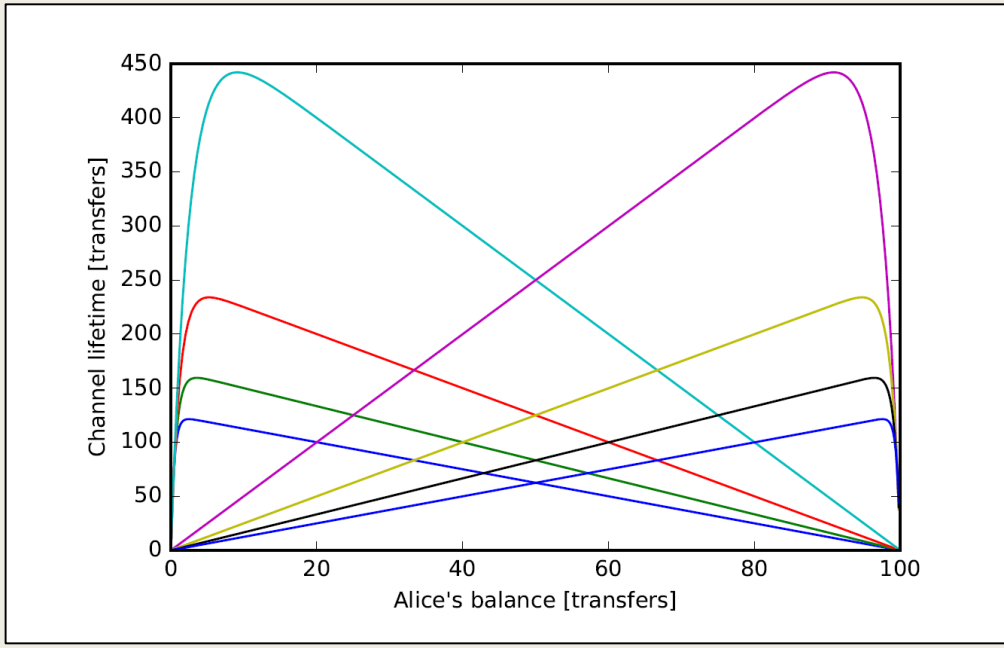
We assume a random walk (biased or unbiased) on the channel state

Basic facts about single channels

- If Alice sends 1 unit to Bob at Poisson rate λ_A,
- Bob sends 1 unit back at rate λ_B,
- there is w units of capacity in the channel,
- m in Alice's hands,

expected channel lifetime:

$$\tilde{X}_m = \frac{m}{\lambda_A - \lambda_B} - \frac{w}{\lambda_A - \lambda_B} \left(\frac{1 - \left(\frac{\lambda_A}{\lambda_B}\right)^m}{1 - \left(\frac{\lambda_A}{\lambda_B}\right)^w} \right)$$



Basic facts about single channels

- If Alice and Bob exchange 1 coin with the same probability, then they will do

$$\mathrm{X_m} = wm - m^2$$

transfers in expectation before hitting the boundary.

- So, if we start a channel funded equally, its expected number of transfers is:

$$\text{Transfers}(w) = \frac{w^2}{4}$$

How much do people transact?

- We make small payments often
- We make large payments infrequently

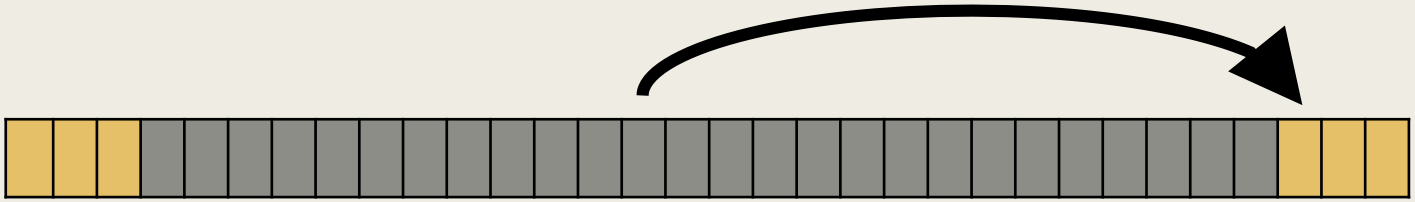
- Data usually shows: power law behavior, e.g.

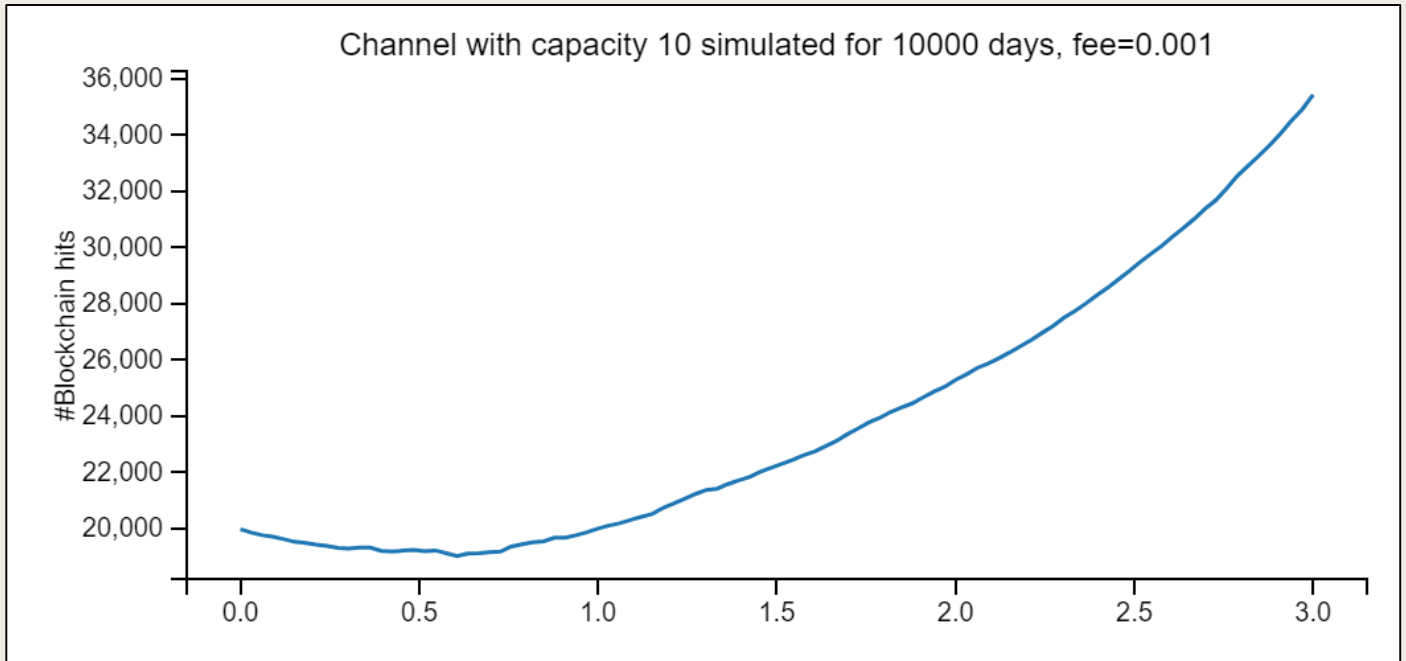
$$fraction\ of\ payments \propto \frac{1}{amount^2}$$

Channel resets

With varying payments sizes:

- When we count the number of blockchain hits, it is profitable to reset the channel near the border





How much do channels cost?

Two main costs:

- Setup and settlement cost of channels (blockchain fee)
- Interest rate payments to fund the channel itself

Fees

- Fixed fees on the blockchain
- But on lightning, larger transactions shorten channel lifetime more. Charge by transfer volume.
- At least to cover costs

Choice

- Txs choose cheapest route (lightning / blockchain)
- Or no route if both are too expensive

Steps in our approach

- Pattern of payment flows and distribution of amounts
- Channel management (topology + funding + reset policy
- Market equilibrium for fees

Some intuition

- Large transfers prefer the blockchain (fixed fee)
- Small transfers split the cost of channel creation

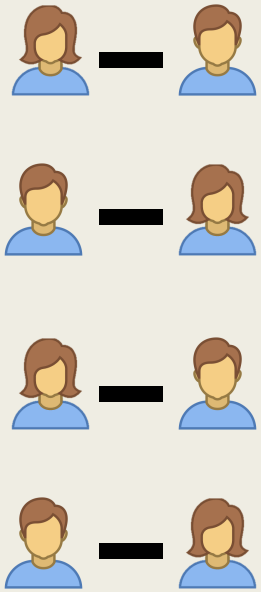
Both compete for blockchain records.

Parameters
(for running example)

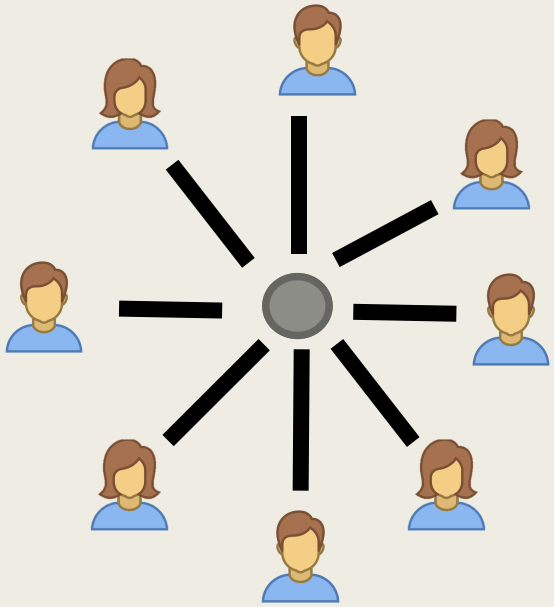
- Each person does 10 txs per day (in expectation)
  - *Drawn from a power law distribution.*
- Willing to pay 1% of transfer size as fees
- 4% yearly interest rate
- 288,000 on-chain records per day (pre segwit)

Topologies

Pairs



Uniform Payments



(with central hub)

Hub: Lots of flexibility, double the channel costs

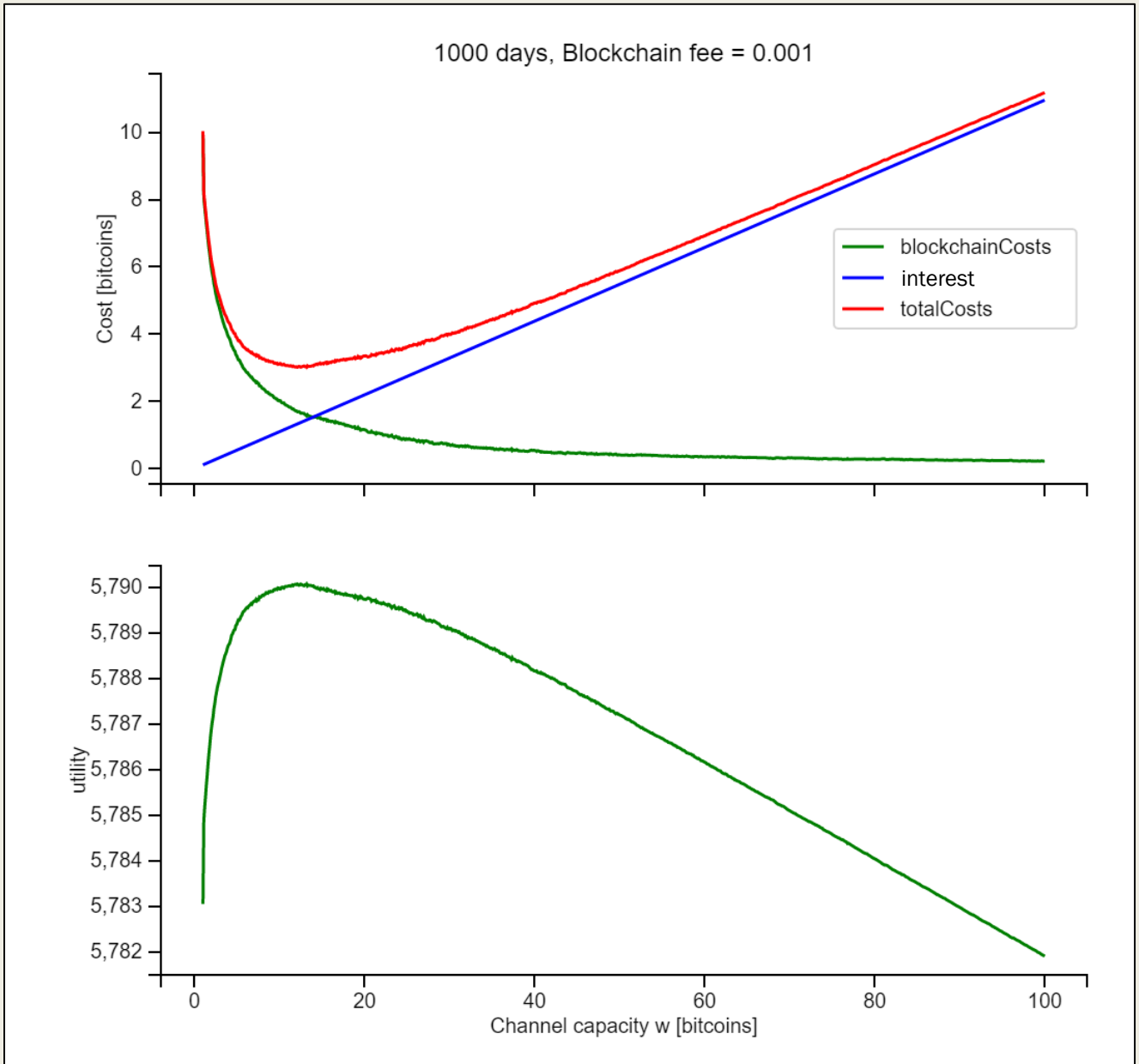
Walkthrough example (in the pairs model)

- Given the on-chain fee we derive:
  - *Optimal reset radius*
  - *Optimal channel funding*
  - *Fee for lightning transactions*
  - *Demand for blockchain records at that price*

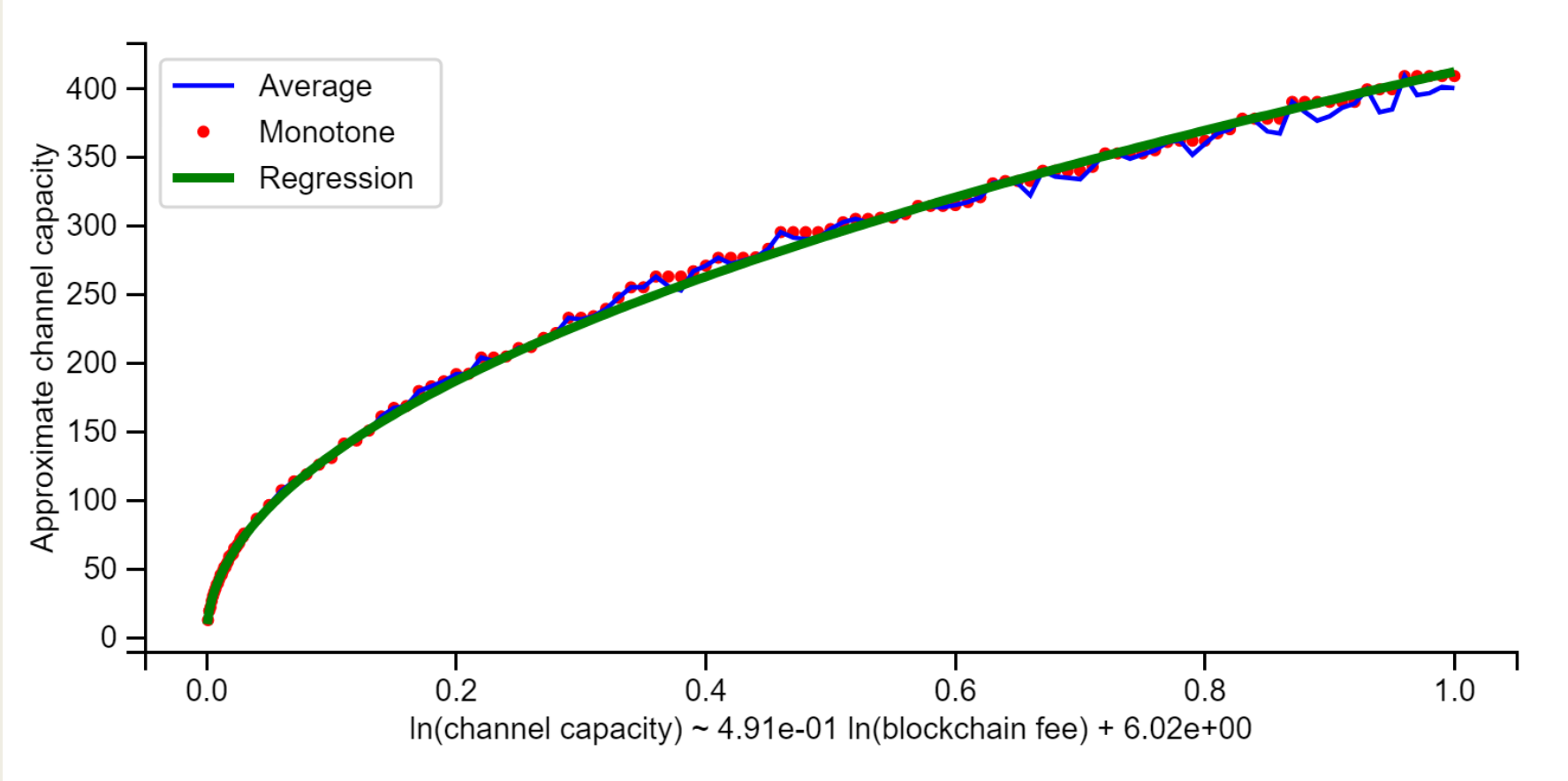
- Then find market clearing fees that sell exactly all blockchain records.

BEHAVIOR OF INDIVIDUALS

Funding the channel

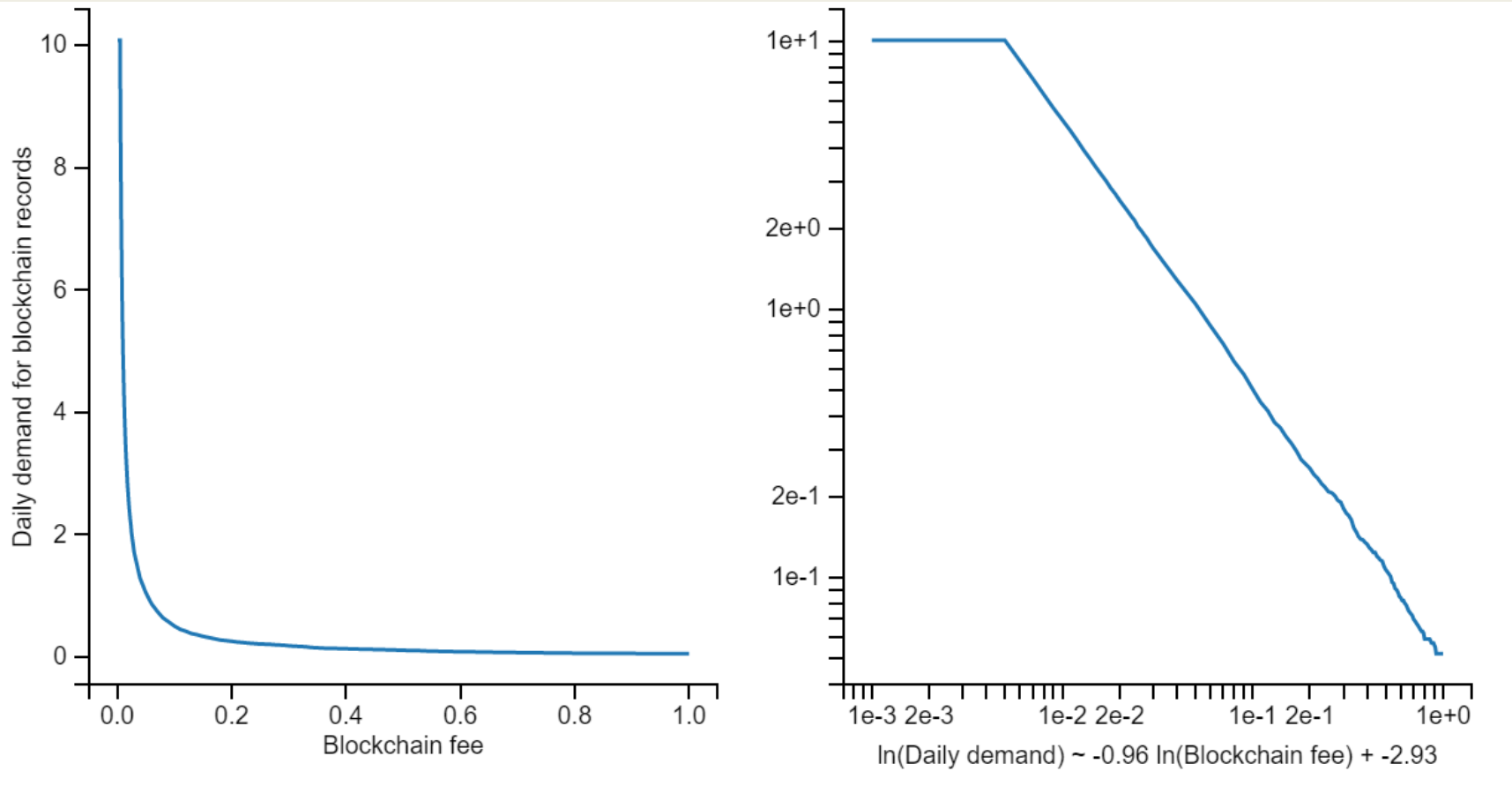


- Channel capacity grows proportionally to $\sqrt{fee}$
- So do interest payments



Demand for blockchain records

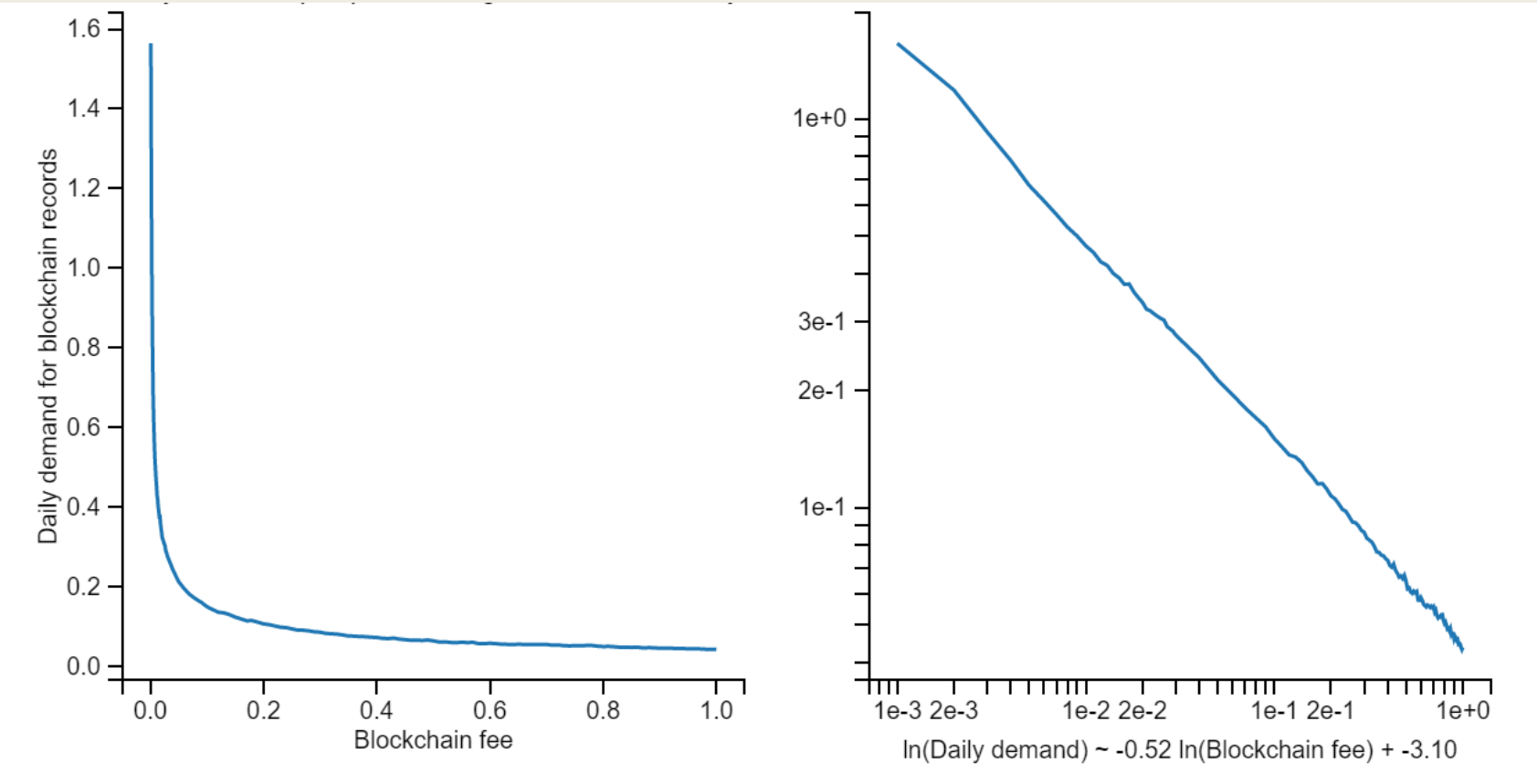
In a world without lightning: demand is $\propto \frac{1}{\text{fee}}$



Demand for blockchain records

In a world with lightning:

- demand $\propto \frac{1}{\sqrt{\text{fee}}}$



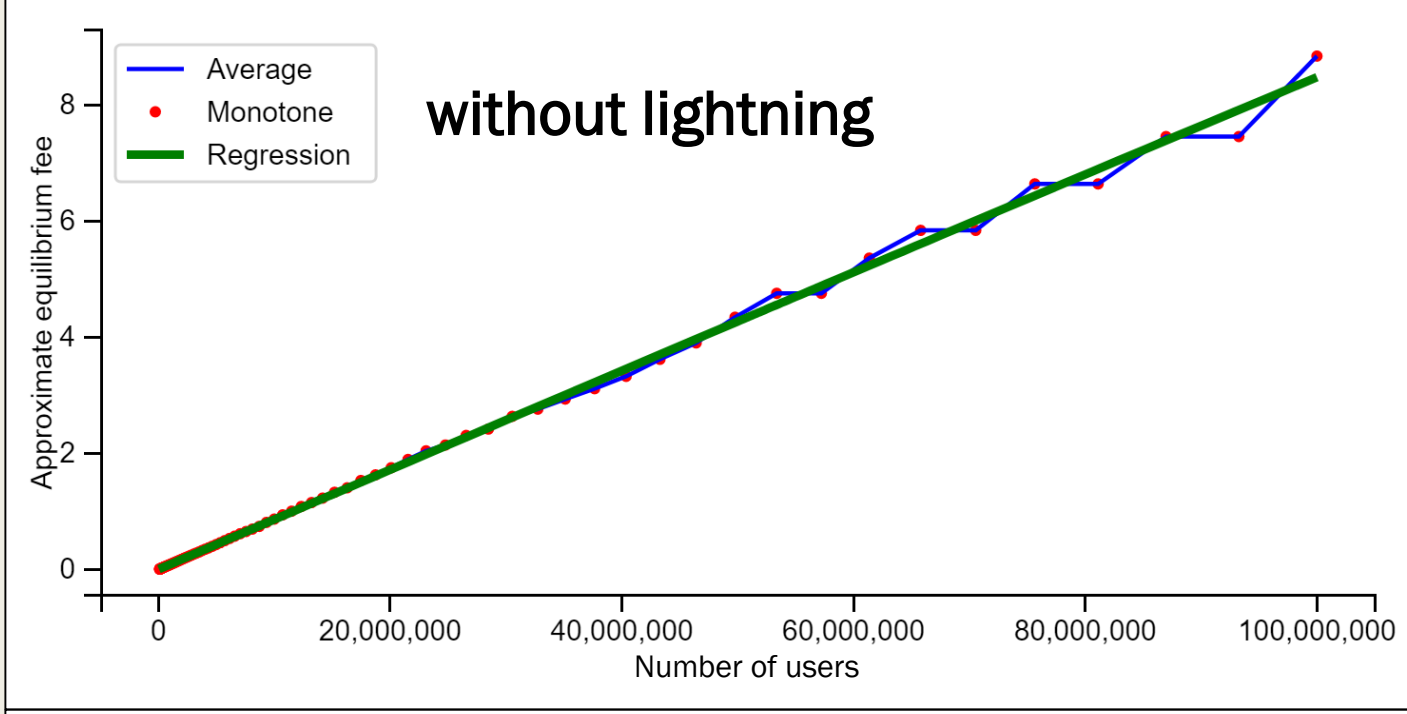
SCALING UP

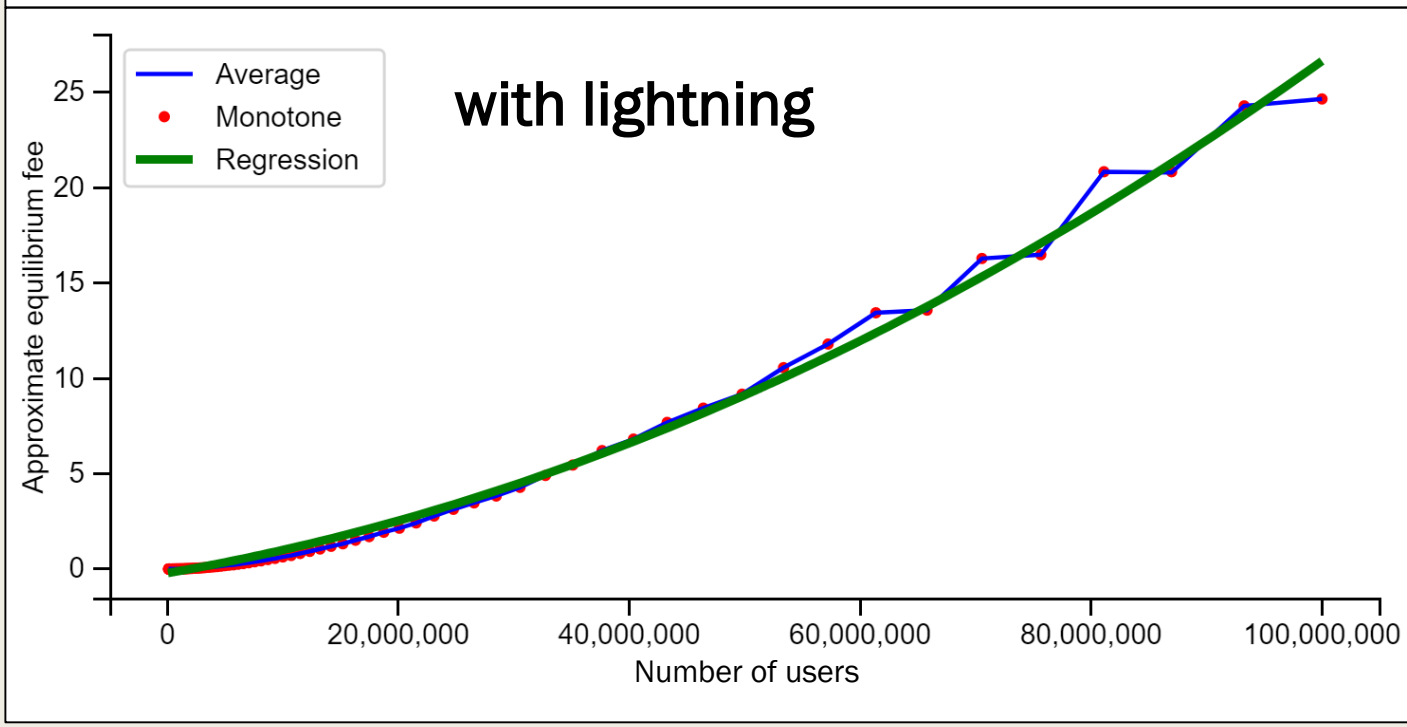
Fees

Fees are lower with lightning up to ~20M

Above 20M lightning fees are higher

Miner revenue is proportional to fees (fixed supply)



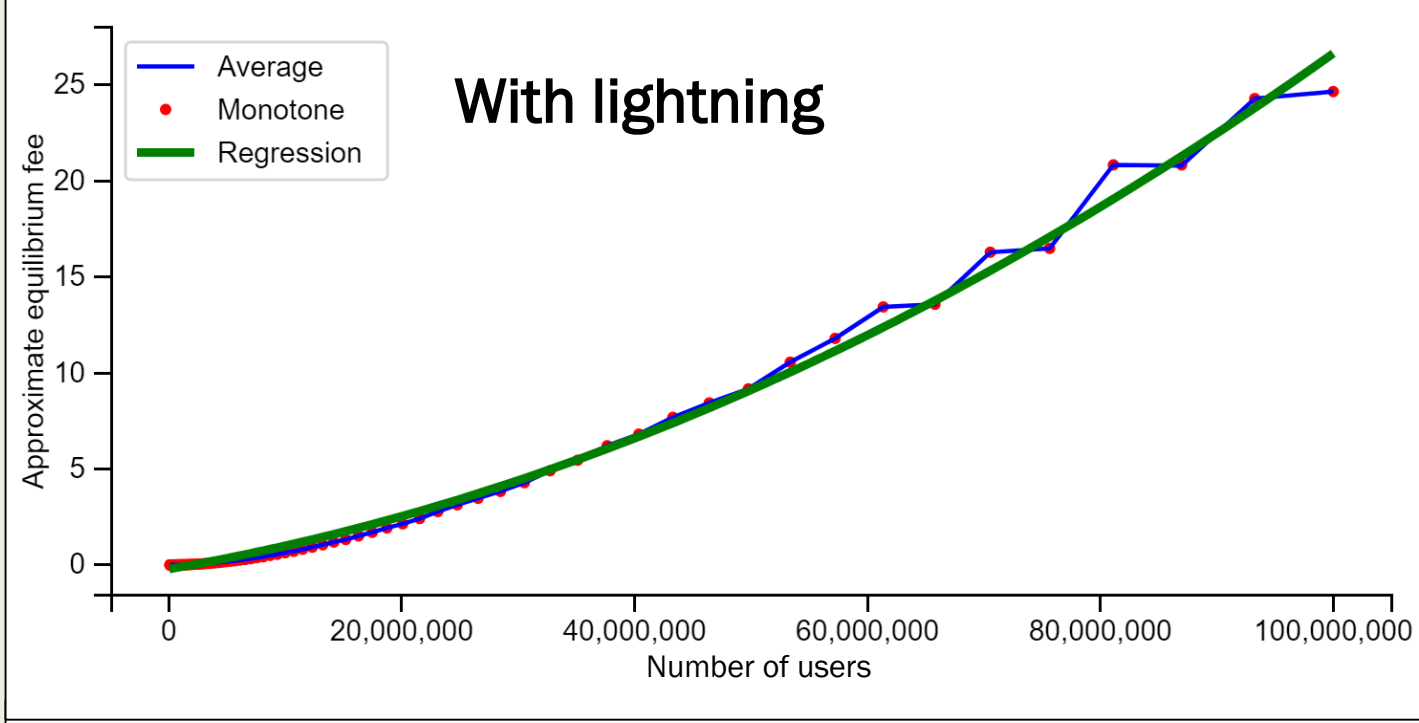


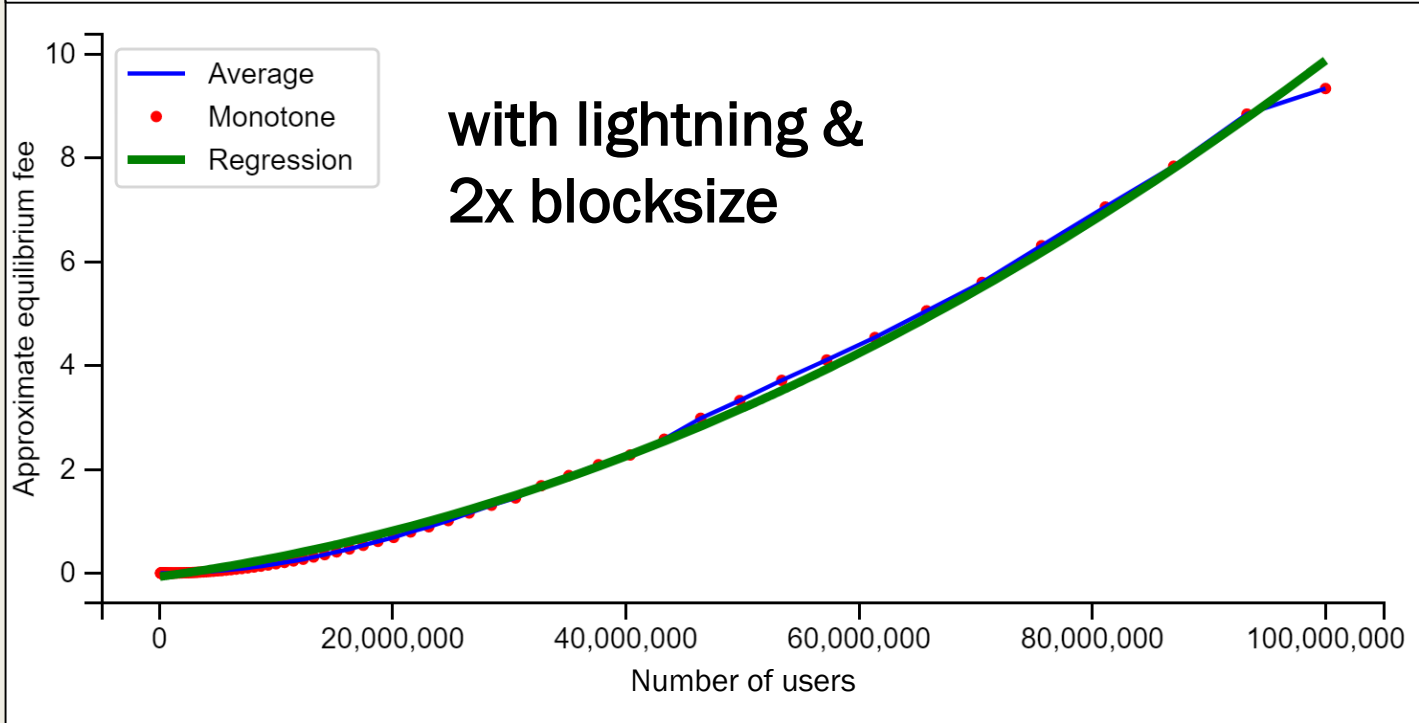
Fees

Blochchain Fees decline more than x2

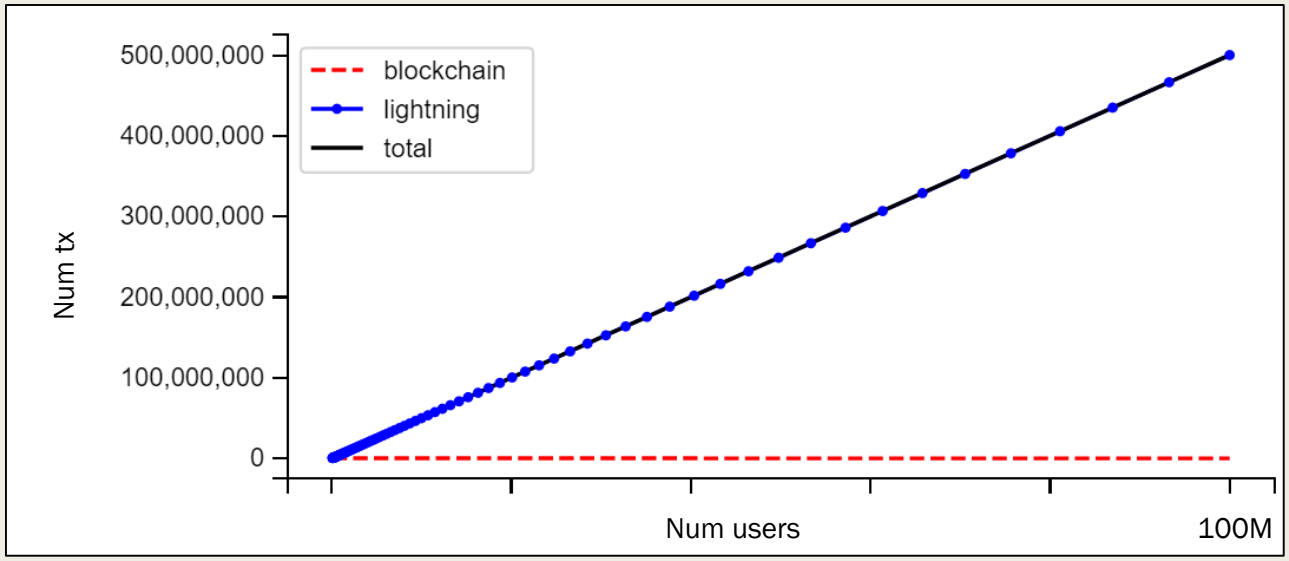
Supply grew x2

Miner Revenue decreased

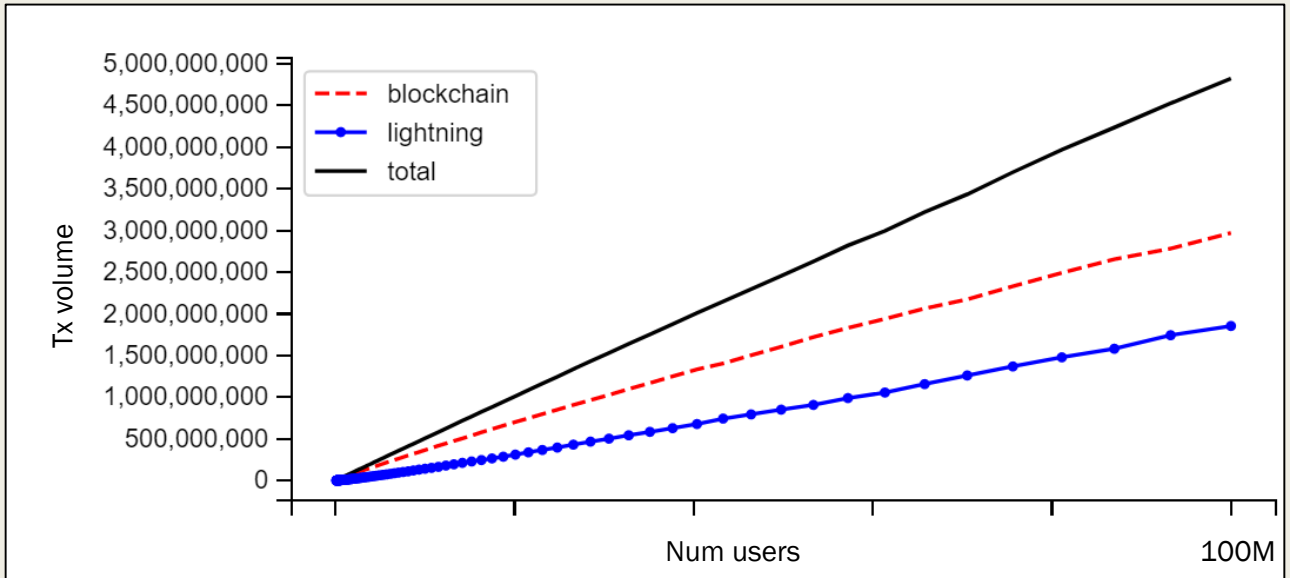




Nearly all transactions go through lightning



But, More volume goes directly via the blockchain



Conclusion

- Lightning helps (by a lot? Not by a lot?)
- 2X Block increases help (not by a lot)

What I did not show

- Heterogenous populations
- More complex patterns of flow
- Other transfer distributions

Concerns

- How fragile / viable is the lightning model?
- Will changes in interest rates & fees have high impact?