Rebalancing in the Lightning Network: Analysis and Implications

Sebastián Reca
Research Scientist at muun

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Financial Costs

- Routing nodes will incur in financial costs by having their money locked.
- Financial costs depend on how much money is locked and the time it is locked.
- Financial costs do NOT depend on routing payments.

The node can decide how to translate these into fees.

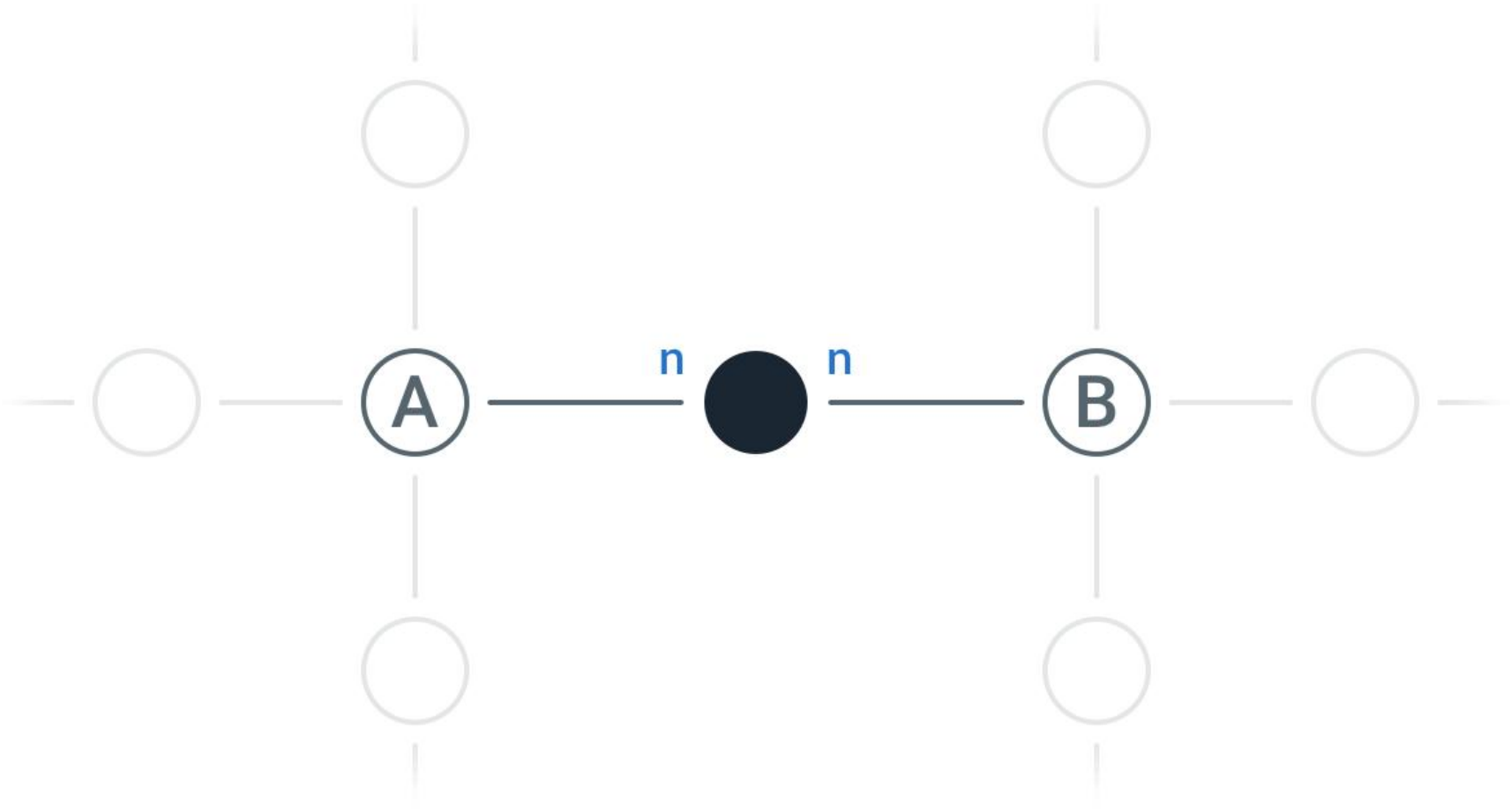
Financial Costs

N = total amount of money locked, r = annual interest rate
Financial costs = Nr

Strategies:

- All payments equal, P ≅ expected number of payments in a year
    - Fee = Nr/P.
    - Penalizes small payments.
- Payments by size, A ≅ expected amount of btc routed per year
    - Fee = zNr/A, where z is the payment amount.
    - Penalizes big payments.

The more payments (or money) routed, the cheaper the fees can be.


A
n
n
B


A
n+1
n−1
B
1


n−4
n+4
A
B
5


A
0
2n
B

Rebalancing: increasing our balance in some channels at the expense of decreasing our balance in some other channels.

Rebalancing: Splicing

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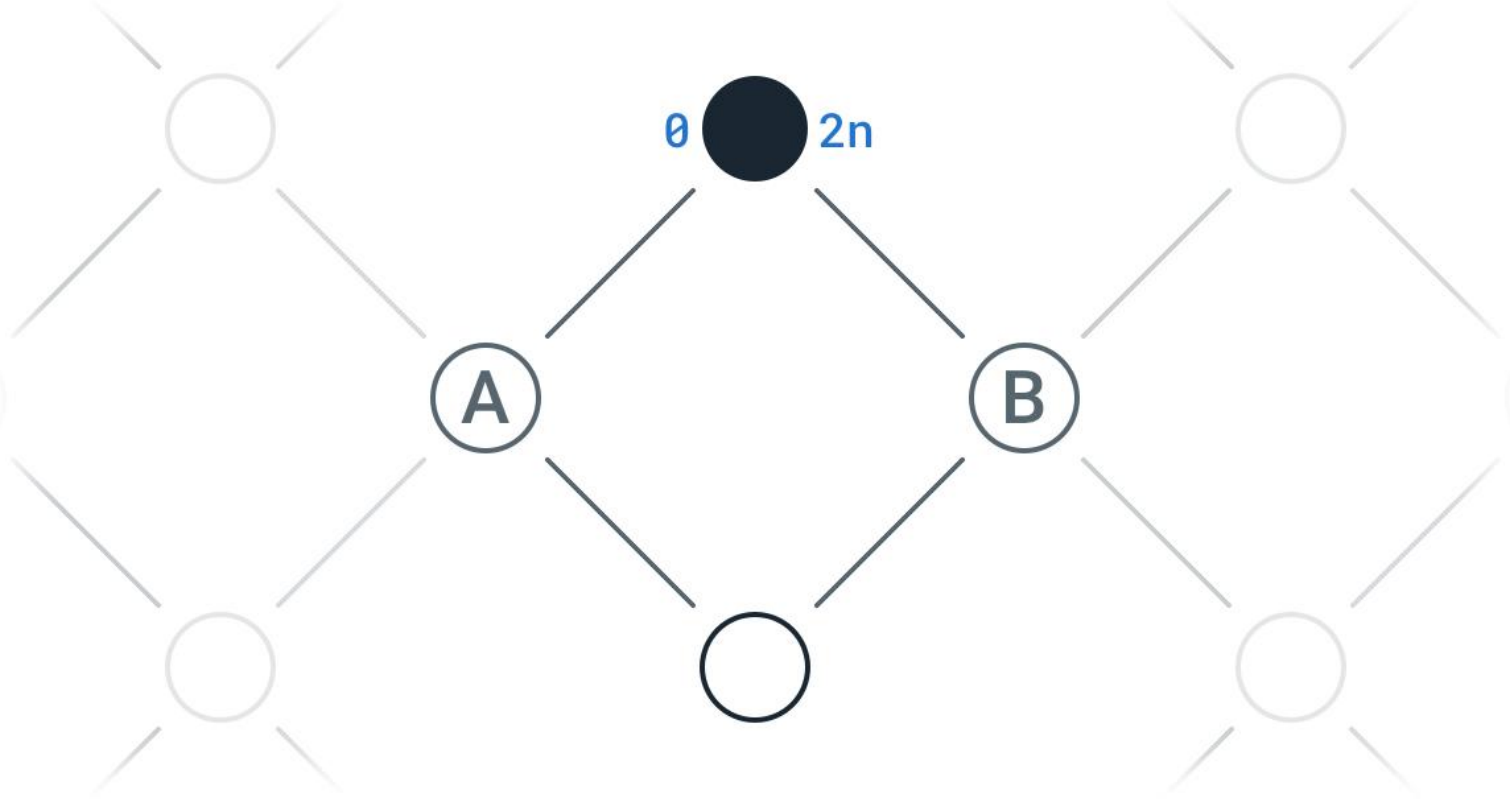
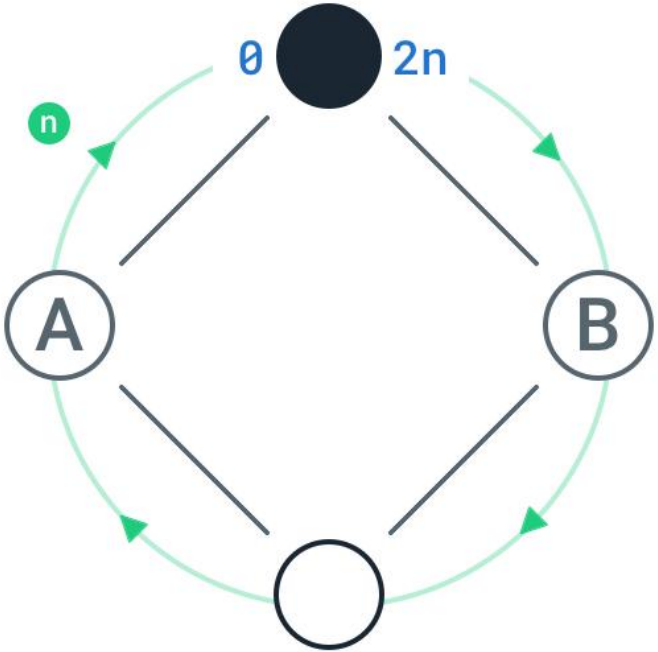
Rebalancing: Splicing

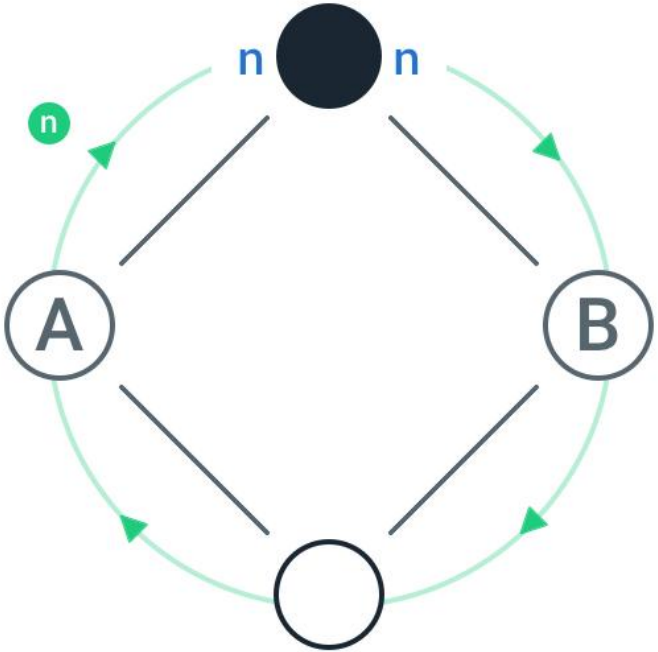
Rebalancing: Circular Payments



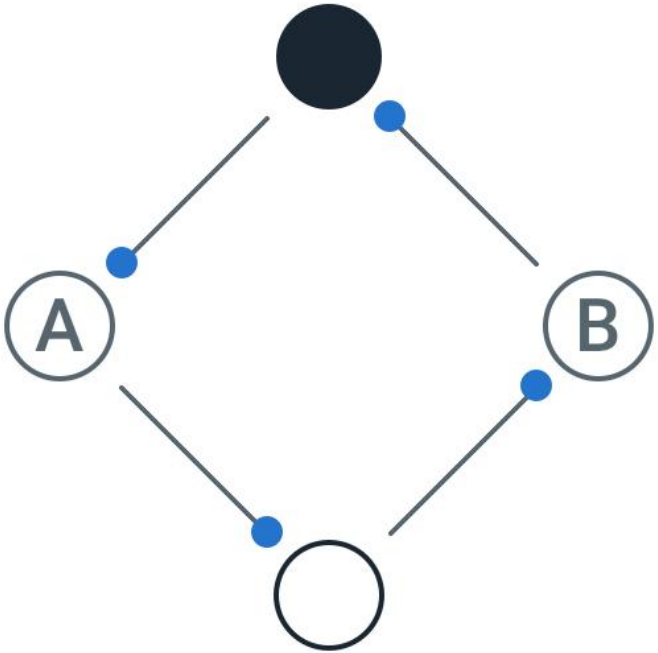
Rebalancing: Circular Payments



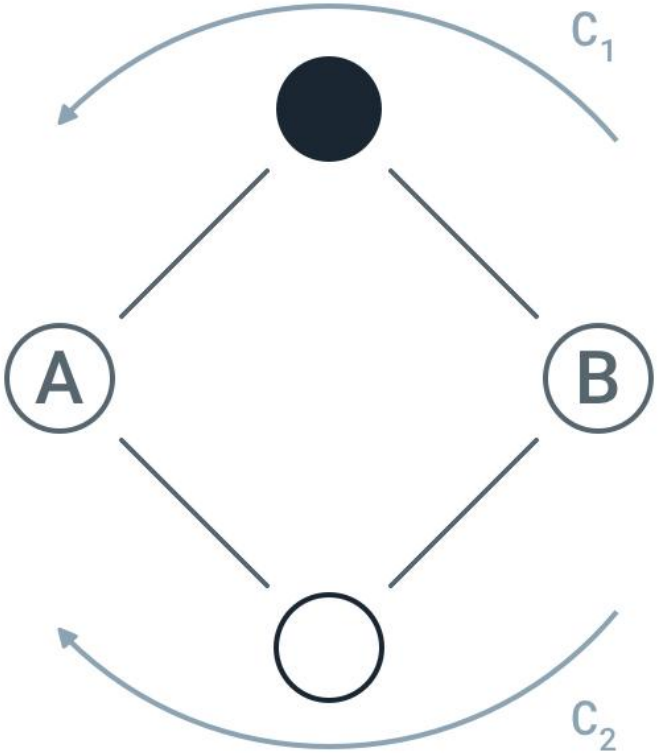
Rebalancing: Circular Payments



Rebalancing: Circular Payments



Network Routing Capacity



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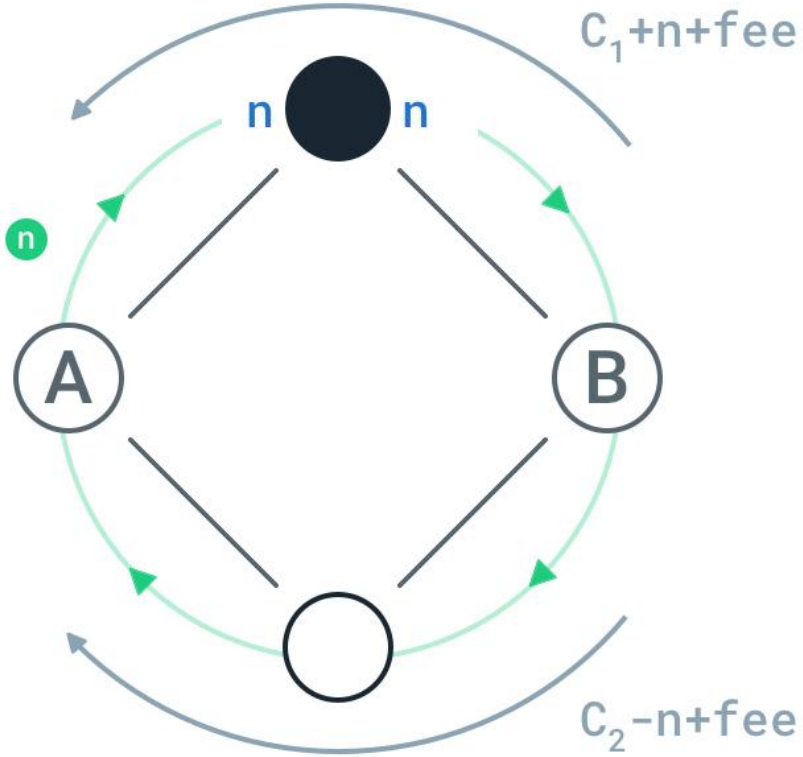

Rebalancing Problem

- Rebalancing channels costs money.
- Optimization problem: how to route the largest amount of money (or payments) while minimizing the rebalancing costs.

The rebalancing problem can be divided into three smaller problems:

1. Prediction of payments
2. Optimization of money distribution

Rebalancing Problem

Optimization of money distribution for 2 nodes

Branzei, Segal-Halevi and Zohar answer this question for the case:

- 2 peer nodes transact following a random process
- One node makes the next payment with probability p and the other one with probability 1 - p.
- All payments of equal size.

Rebalancing Problem

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The rebalancing problem can be divided into three smaller problems:

1. Prediction of payments
2. Optimization of money distribution
3. Rebalancing

Simulation model

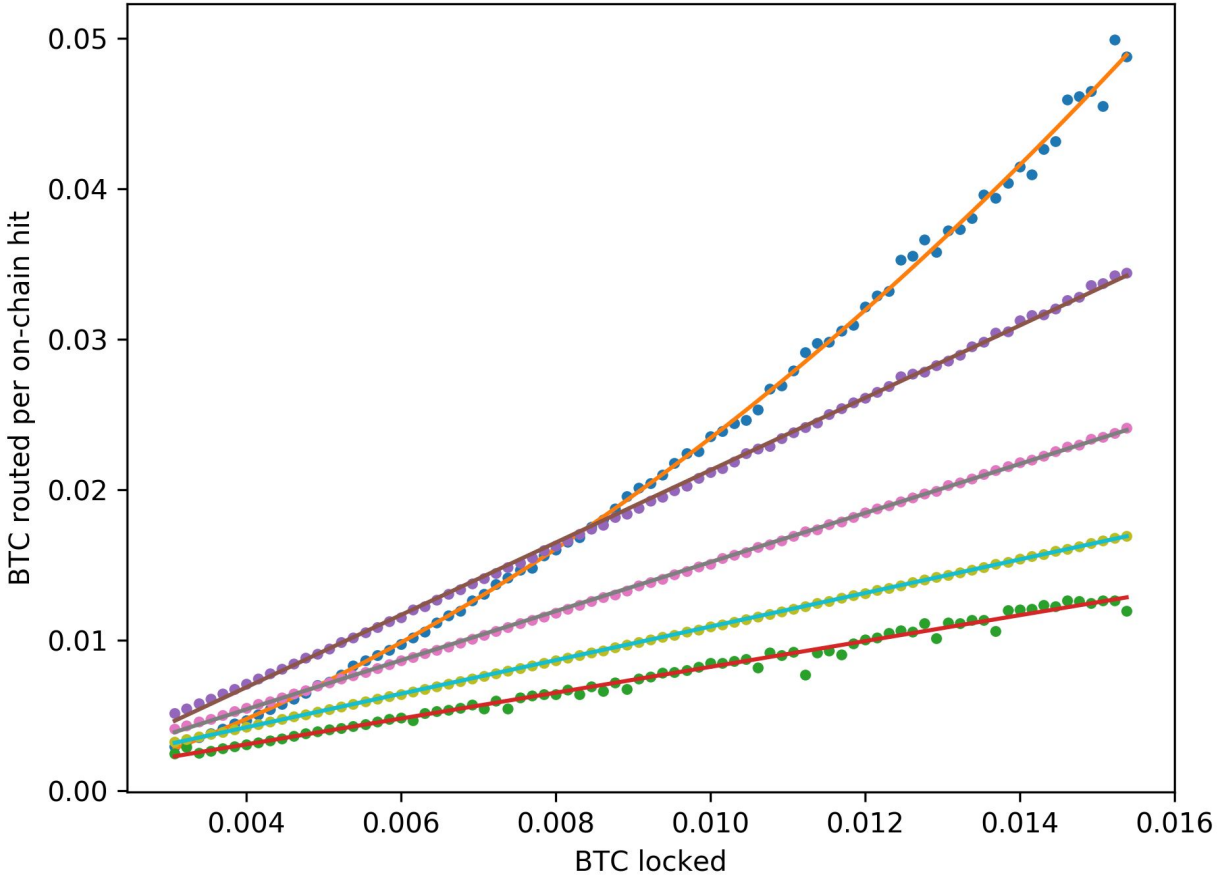
Input:

- N btc to lock
- Connected to M nodes
- Peer nodes transact with each other following a payment rate matrix R, where $R_{i,j}$ = probability of node i making the next payment to node j.
- Payment amounts follow certain given distribution.

Output:

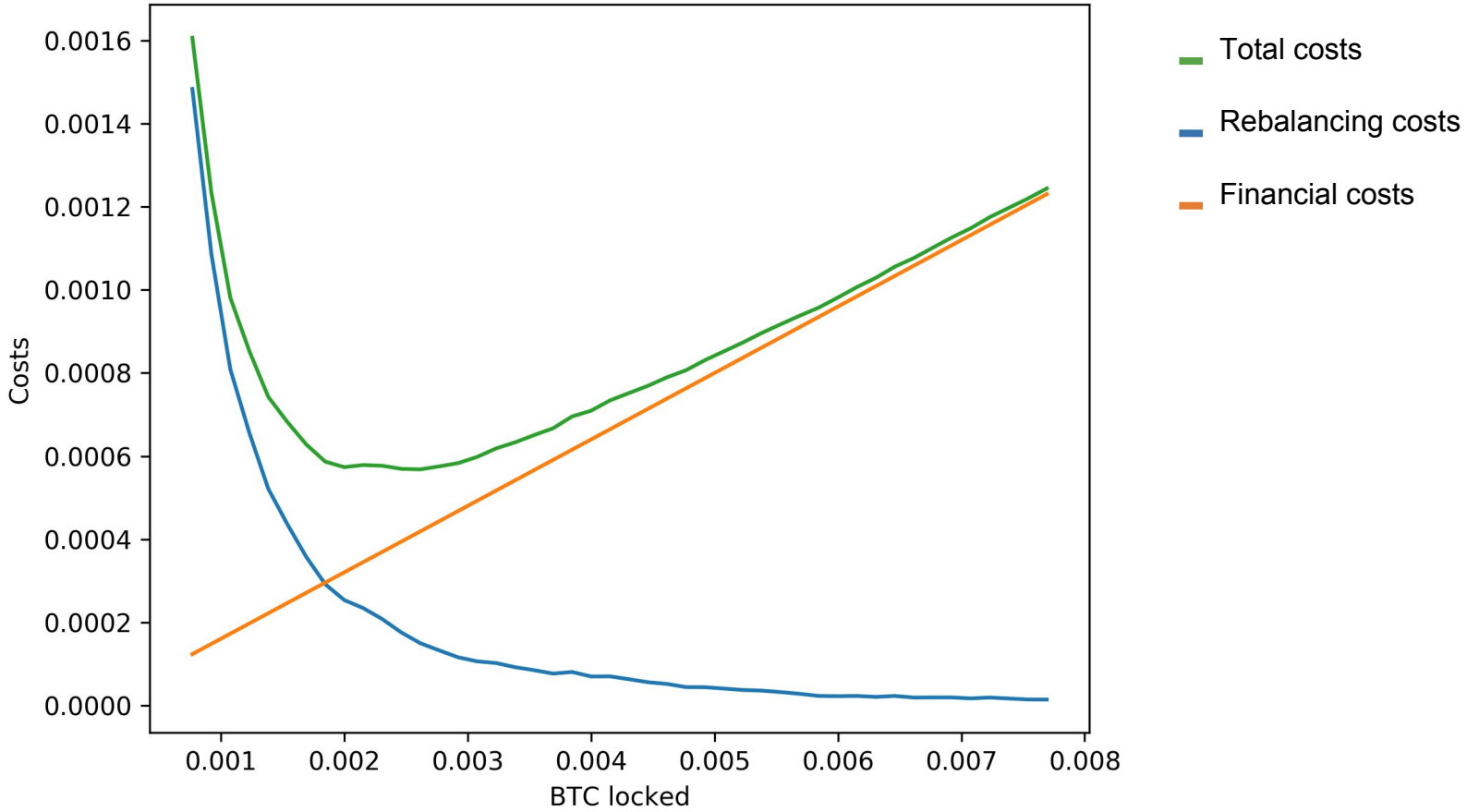
- Amount of routed money
- Amount of routed payments
- Rebalancing operations needed, that is, on-chain hits.

How does the amount of money locked impact the need for rebalancing?

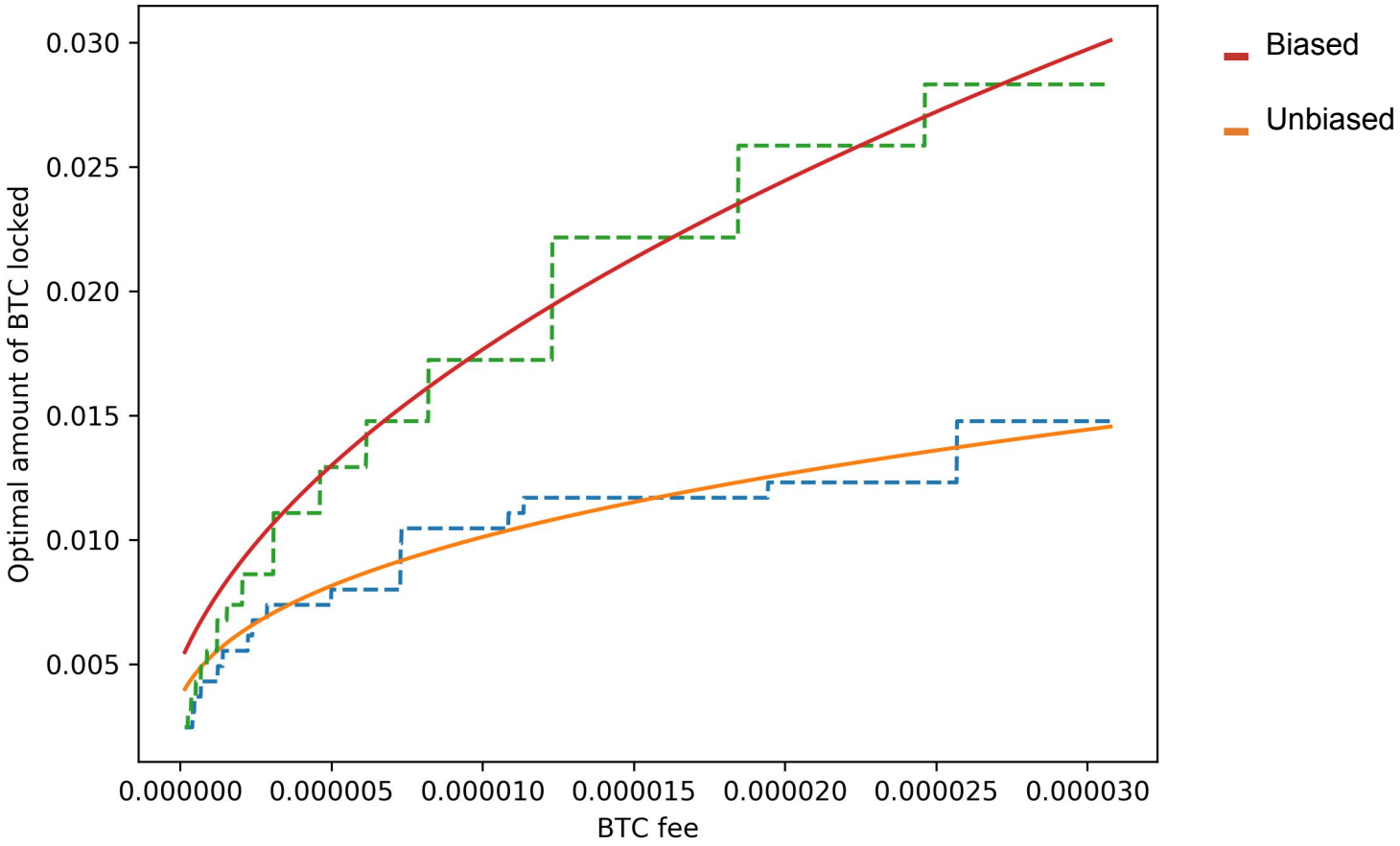


Nodes = 4
Distribution = Pareto (scale 2)

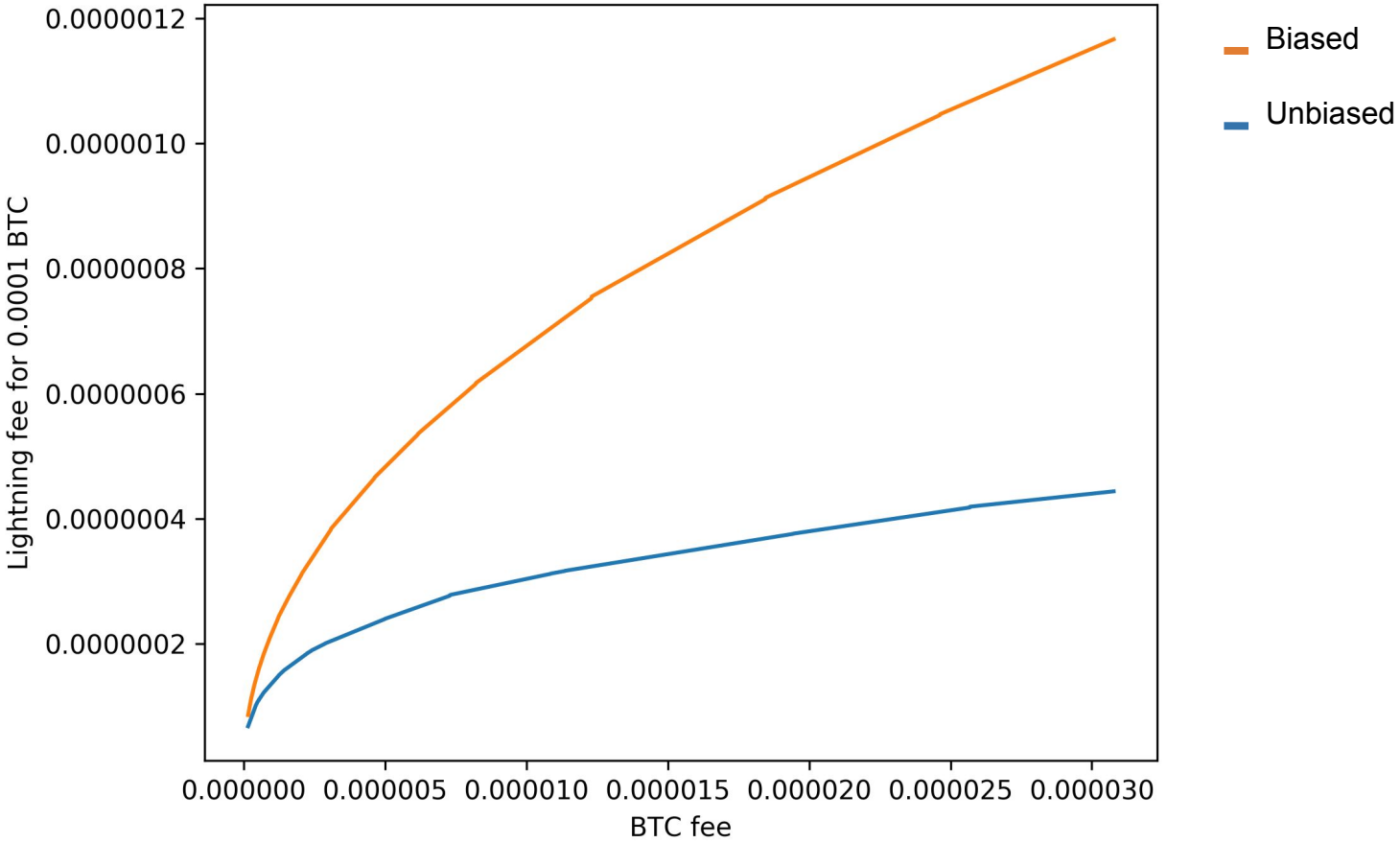
How does rebalancing costs add to the total costs of having a routing node?



How does the Bitcoin fee impact the optimal amount of money locked in nodes?



How does the Bitcoin fee impact the lightning fees?



Conclusions

- All routing nodes in the LN will face the rebalancing problem and its costs.
- Routing nodes will be economically incentivized to correctly predict payments.
- Linear fees make sense in the LN
- The optimal amount of money to be locked inside channels will grow with Bitcoin fees.
- Lightning fees will grow with Bitcoin fees.