Rebalancing in the Lightning Network: Analysis and Implications

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

2n unlocked
Rebalancing: Splicing
Rebalancing: Circular Payments
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Network Routing Capacity
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Diagram showing network topology with nodes A and B, and intermediate nodes n. Arrows indicating flow with equations $C_1 + n + \text{fee}$ and $C_2 - n + \text{fee}$.
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.