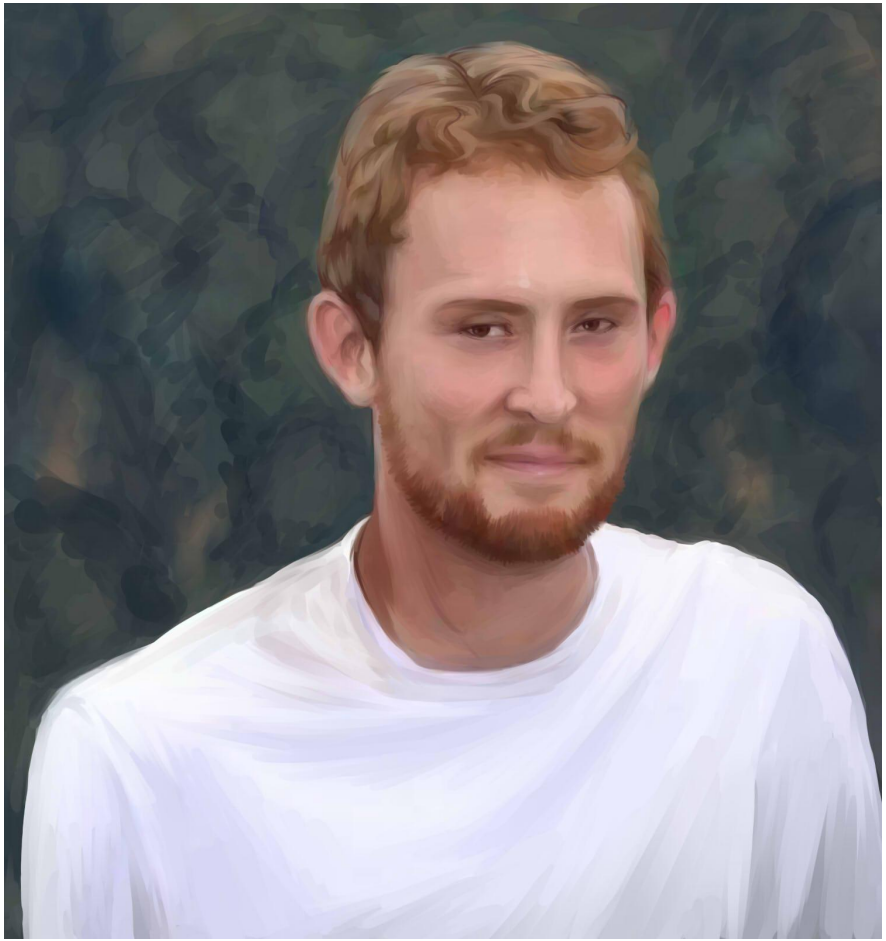

The Lightning Network
Thunderstruck!



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@BitGo

World Traveler

github.com/Melvillian

Main Goal: How to use the Lightning Network

- What immediate problems does Lightning solve?
- What will Lightning allow us to do that we can’t do now?
- What is Lightning?
- RPC commands to operating *lnd*
- How does Lightning work?
- Future use of Lightning: Neutrino
- Readings for future study

Transaction Scalability:

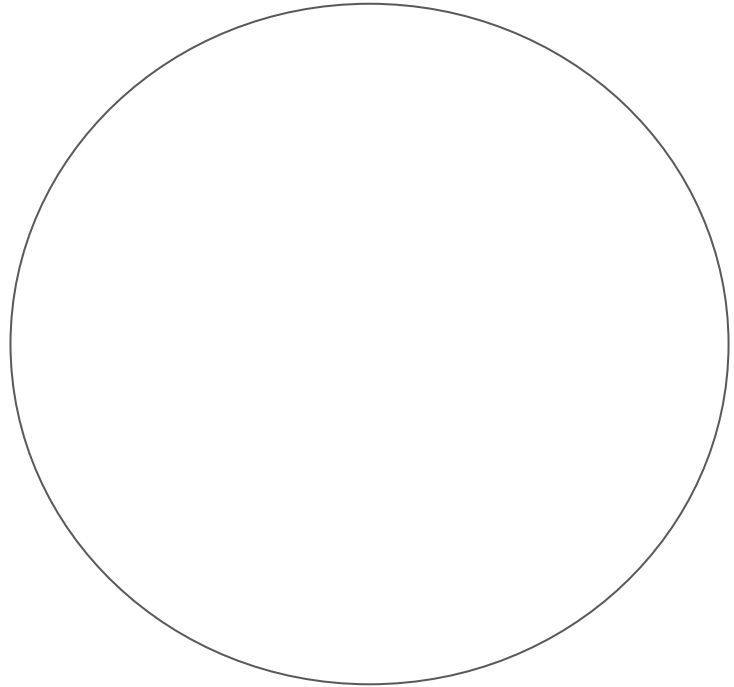
Transactions per second (TPS)

Average: 4
Peak: 7

Average*: 8
Peak: 14

Average: 200
Peak: 400

Average: 2000
Peak: 56,000



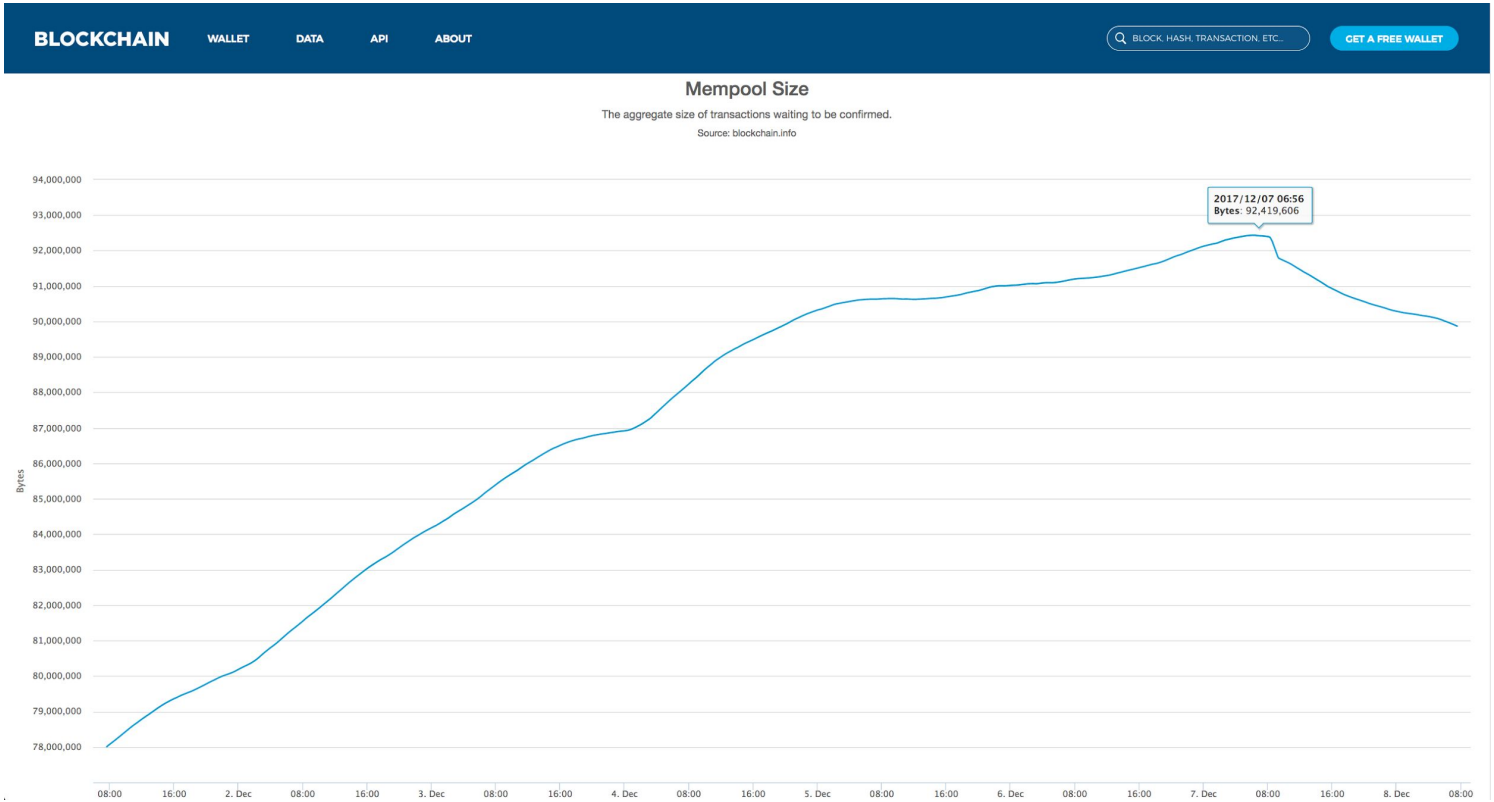
bitcoin

bitcoin CASH

bitcoin 50x

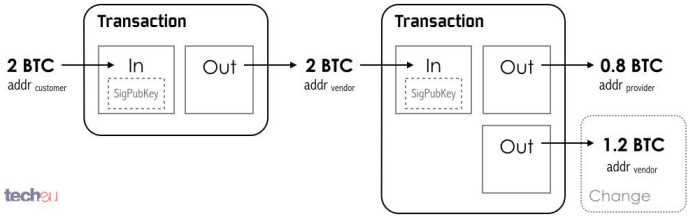
VISA

Transaction Backlog



How does it scale?

- Removes the need to make on chain transactions for payments.
- User wallets manage a smart contract with several payment nodes
- The contract is fully backed by bitcoin, but can be updated locally between the two nodes
- Contract updates can be chained so any connected node can pay any other.



- **Rarely need to talk to him**
- **Especially if we know 100% what he will decide**

Light Clients & Contract Enforcement

- Light clients are users of the bitcoin ecosystem that do not download and verify the whole blockchain
- We aspire that light clients do not trust, current wallets work by
  - Comparing headers with difficulty
  - Bloom filters
  - Merkle Trees
- Compact block filter headers
  - Reverses the filter dynamic
- Trust model changes when you are managing payment channel contracts
  - We can outsource channel monitoring

Poon-Dryja Channel:

- Each side of the channel maintains it's own version of transactions
-

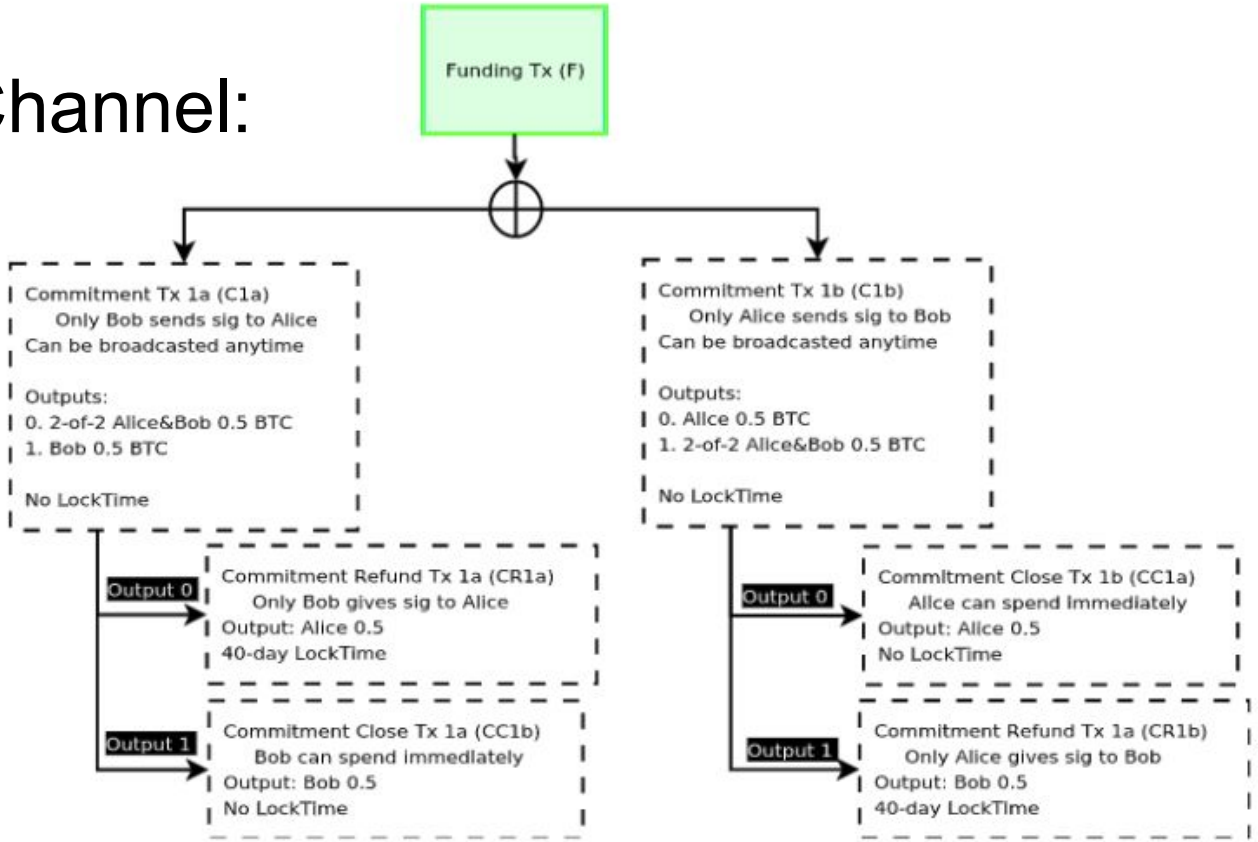


Figure 1: Figure 1 from the Lightning Network Draft 0.5

Future Improvements from Lightning

Instant Payments to anyone

Future Improvements from Lightning

Micropayments

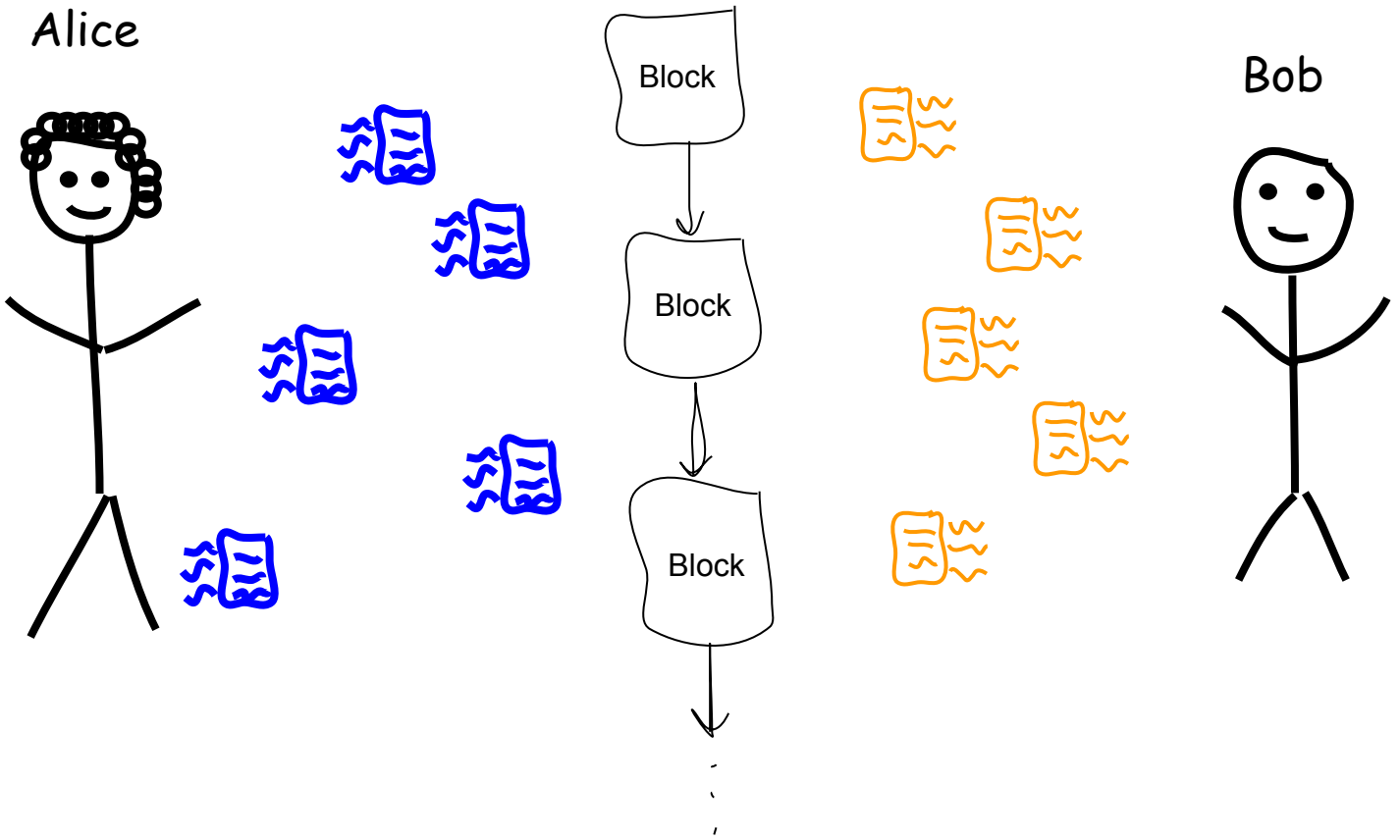
Future Improvements from Lightning

Cross-chain Atomic Swaps

Break...

So….
What is Lightning?

Think of Lightning as a System of Secure IOUs



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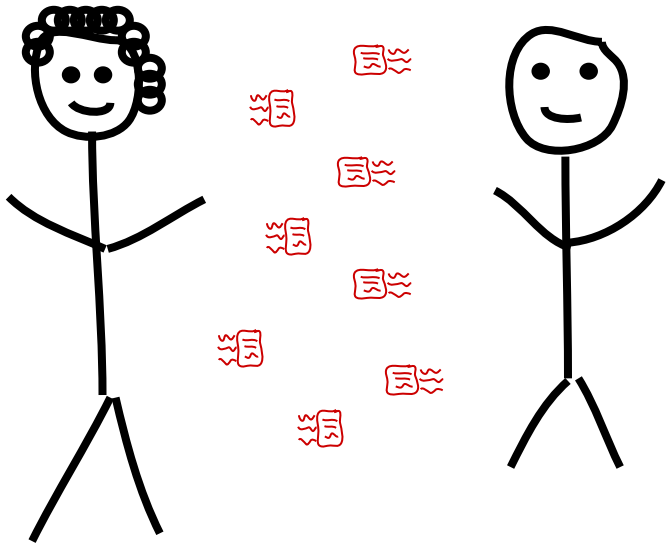

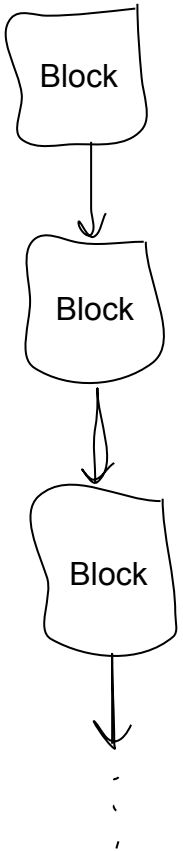

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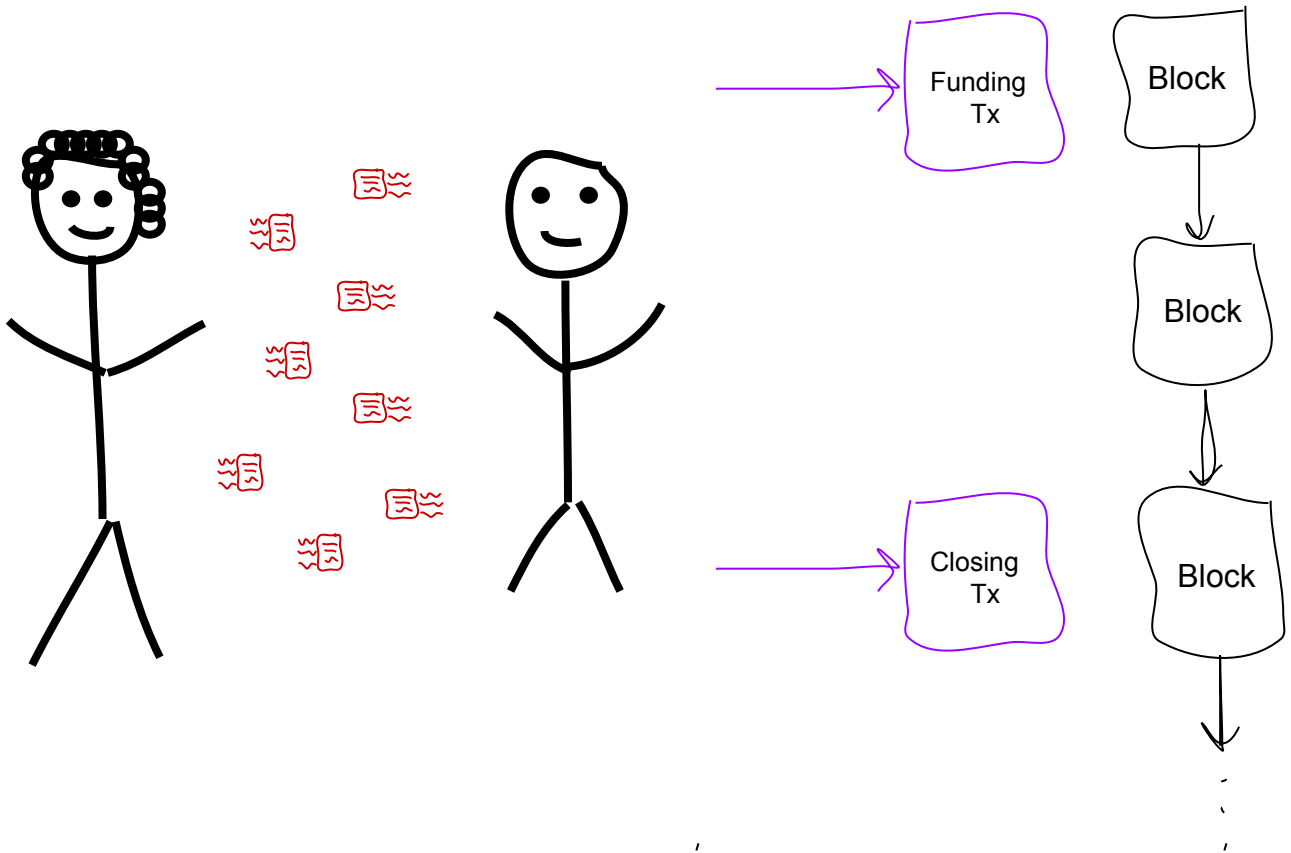

What does Lightning Look Like?

lncli

Command-line client used to send JSON-RPC requests to *lnd* (written in Golang)

lnd

Lightning-aware node which handles channel management, private/public key storage, and peer communication. Used *btcd* to interact with blockchain (both are written in Golang)

What does Lightning Look Like?

- Download + install *lnd* + *lncli*
  - https://github.com/lightningnetwork/lnd/blob/master/docs/INSTALL.md

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- Fund Wallets

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  - *lnccli unlock*
- Fund Wallets
- Create Payment Channel
  - *lncli connect 033f05189c200b946097ed0a81e1d47ec1b83ba5343670d1500659ac74be21de51@159.203.125.125*
  - *lnccli openchannel --node_key=033f05189c200b946097ed0a81e1d47ec1b83ba5343670d1500659ac74be21de51 --local_amt=100000000*

What does Lightning Look Like?

- Send funds!
  - *lncli addinvoice --value=1000*
    - *"pay_req": "lntb100u1pdza8wmpp570kl3xp8psz4enjcxrlv66xmssj044hfe37nntd9waq0rwjs0hlqdqqcqzystdrasw9ufy30q9dv9awa0tw2lurm9dgw4updpk4dlx4hz4jugf65454usjmyu9w6vrj6tny7fw4uz56x3x2q6c6q2wgwfq9hapyz4ugqhedxqu"*
  - *lncli sendpayment --pay_req=lntb100u1pdza8wmpp570kl3xp8psz4enjcxrlv66xmssj044hfe37nntd9waq0rwjs0hlqdqqcqzystdrasw9ufy30q9dv9awa0tw2lurm9dgw4updpk4dlx4hz4jugf65454usjmyu9w6vrj6tny7fw4uz56x3x2q6c6q2wgwfq9hapyz4ugqhedxqu*
- Side-note: Lightning in it's current form is pull-based, you can't send funds to nodes without them first requesting you send them (different from underlying Bitcoin way of sending, which is push-based)

What does Lightning Look Like?

- Close the channel
  - *lncli closechannel --funding_txid=5fb65faf5ef665284bd82db5077b26d8eb3617cdb7e143a6bbef4e6301b41221 --output_index=0*

What does Lightning Look Like?

Demo!

What does Lightning Look Like?

Demo!

…come up and talk afterwards

Break...

How Does Lightning Work?

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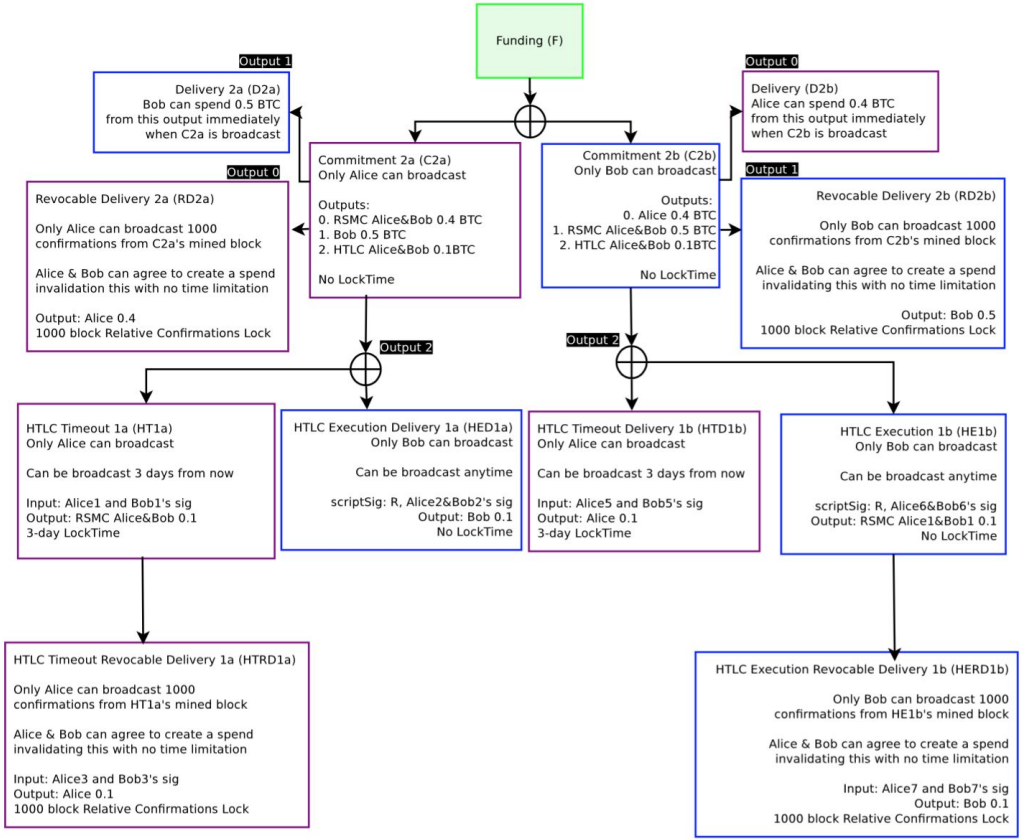

How Does Lightning Work?

- Smart Contracts (Bitcoin SCRIPT language)
- Multisignature addresses
  - Funding transaction
  - Commitment Transactions
- Time-locked Transactions
- Revocation Transactions
- Hash Time-locked Transactions

Smart Contracts (SCRIPT)

- Addresses are not what you think they are
  - Addresses are mini programs which, if upon ending return TRUE, prove ownership of coin
  - Address -> scriptPubKey (like a callback)
  - Ownership -> scriptSig (like arguments to the callback)

```
scriptPubKey: OP_DUP OP_HASH160 <pubKeyHash> OP_EQUALVERIFY OP_CHECKSIG
```

```
scriptSig: <sig> <pubKey>
```

Funding Transaction

- Used to open/fund the the Alice-Bob channel
  - Alice and Bob each generate a keypair
  - Broadcast the transaction to the blockchain, wait for it to confirm
  - Happens after Commitment transactions are exchanged
- 2-2 multisig address
  - Requires 2 signatures, one from Alice, one from Bob, in order to be valid
  - Ensures both Alice and Bob must agree before moving any funds
  - Uses P2SH (Pay to Script Hash) address types

```
scriptPubKey: 2 <alicePubKey> <bobPubKey> 2 OP_CHECKMULTISIG
```

```
scriptSig: OP_0 <aliceSignature> <bobSignature> 2
<alicePubKey> <bobPubKey> 2 OP_CHECKMULTISIG
```

Commitment Transaction

- Represents the current state of the channel
  - How much coin do Alice and Bob have
- Protects Alice and Bob from being hurt if either is uncooperative
- If broadcasted, broadcaster must wait some time before claiming funds, but other channel member can claim their funds immediately

```
OP_IF
    # Penalty transaction
    <revocationkey>
OP_ELSE
    `to_self_delay`
    OP_CSV
    OP_DROP
    <local_delayedkey>
OP_ENDIF
OP_CHECKSIG
```

Future Study

Master resource list (you will know more than me after watching/reading all of this)

- http://dev.lightning.community/resources/

Mid-level explanation of Lightning

- http://dev.lightning.community/tutorial/01-lncli/index.html

Summaries of major BOLTs (Lightning's version of BIPs) by core dev Rusty Russell

- https://medium.com/@rusty_lightning/the-bitcoin-lightning-spec-part-1-8-a7720fb1b4da

Tutorial on how to setup 3 lightning nodes and make payments

- http://dev.lightning.community/tutorial/01-lncli/index.html

API docs for *lnd*

- http://api.lightning.community/

Original Lightning Network Whitepaper

- https://lightning.network/lightning-network-paper.pdf

Further Future Study

Core Lightning Developer Blog

- https://rusty.ozlabs.org/?p=462

Good SO post explaing Lightning

- https://bitcoin.stackexchange.com/questions/48283/what-is-the-lightning-network-proposal-what-problem-is-it-trying-to-solve

Transaction Timelock Explanation

- https://en.bitcoin.it/wiki/Timelock

2015 Explanation of Lightning Network (useful when trying to understand what's changed)

- https://github.com/ElementsProject/lightning/blob/master/doc/deployable-lightning.pdf

Further Watching

- https://www.youtube.com/watch?v=7FWKc8lM4Ek