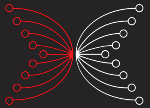
# Smart Contracts

## Lightning

Lars Brünjes



INPUT | OUTPUT

January 9 2020

# Introduction

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  - The Lightning-Network is one way to solve this problem.
  - It is initially planned for Bitcoin, but its idea is generic enough to apply to many other cryptocurrencies (including Cardano).
  - The basic idea is to offload work from nodes by creating parallel side channels, which can process the bulk of all transactions.

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- In spite of this, all payments using the channel are secure and are guaranteed by the blockchain.
- After we will have understood how such a channel between two parties works, we will see how that system can be extended to allow payments between parties who do not possess a direct channel between each other.

# Direct Payment Channels

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  3. Alice creates and signs a new transaction, which has the multisig-address as input and two outputs, her deposit to herself, Bob's deposit to a new multisig-address, which can either be unlocked by Bob after 1000 blocks or immediately by Alice, if she knows Bob's secret.
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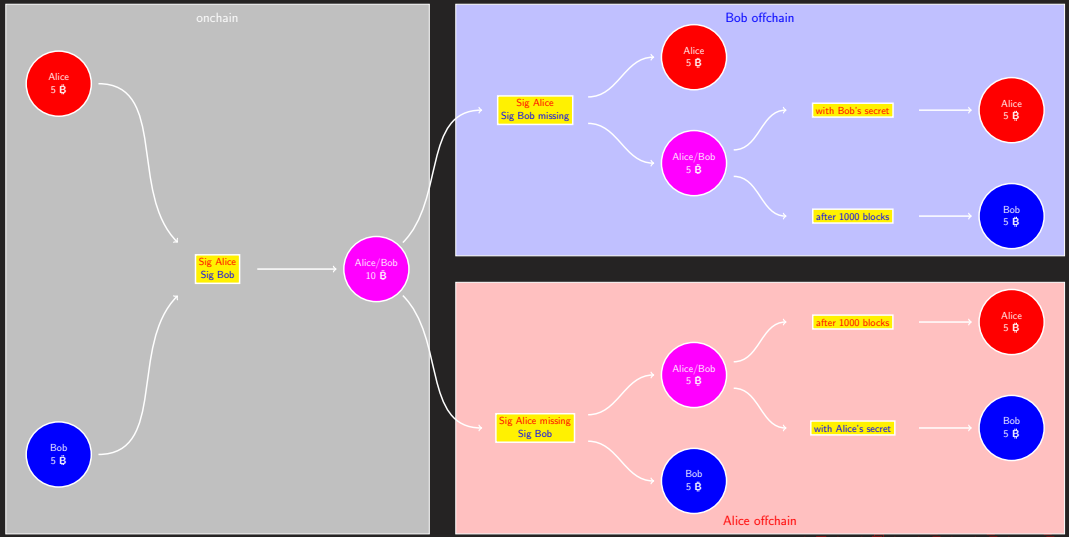
  6. Finally, Alice and Bob sign the transaction from step-1 and send it to the blockchain.

# Illustration



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- If Alice wants to retrieve her deposit without Bob's help, she signs the transaction she received from Bob and sends it to the blockchain.
  - Bob gets his deposit immediately.
  - Alice must wait for 1000 blocks until she gets her deposit.
  - If Bob manages to learn Alice's secret in the meantime, he can get his hands on Alice's deposit before the 1000 blocks are over. (We will see later what this is good for.)

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  3. Bob creates, signs and sends Alice a new transaction with the multisig-address as input and two outputs — 6 ₿ to himself, 4 ₿ to a new multisig-address, which can be unlocked either after 1000 blocks by Alice or immediately by Bob, provided he has learned Alice's new secret.

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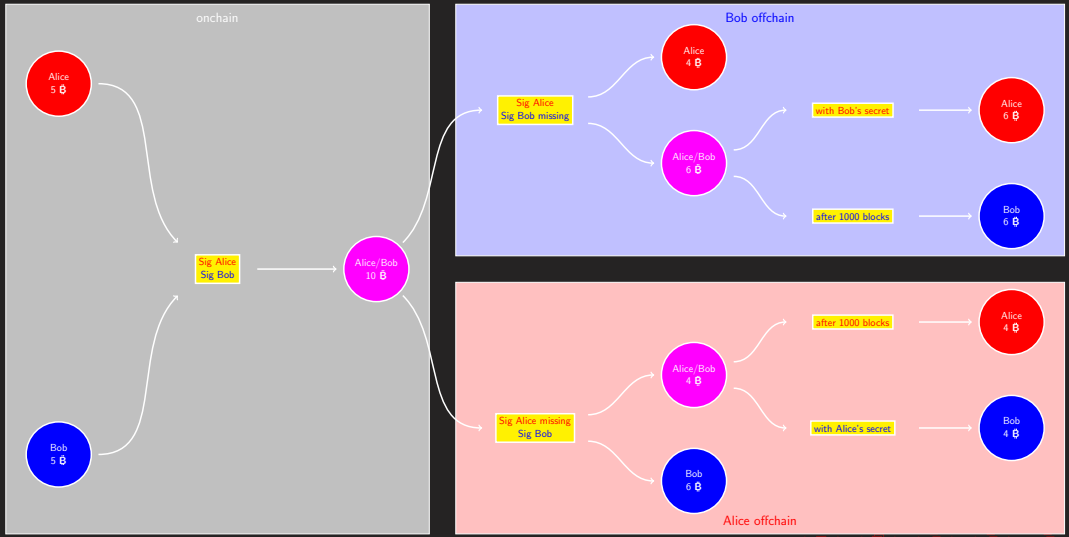

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- As before, Alice can retrieve her 4 Ƀ without Bob's help by sending the new transaction she received from Bob to the blockchain.
- If she instead tries to use Bob's old transaction, she will have to wait for 1000 blocks for her 5 Ƀ. But Bob knows her old secret now and can get all the money for himself in this case. This means that Bob's old transaction is now worthless for Alice.

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- As before, Bob can retrieve his 6 ฿ without Alice's help by sending the new transaction he received from Alice to the blockchain.
- He has no interest in using Alice's old transaction, because that one only gives him 5 ฿ instead of 6 ฿. In addition to that, Alice could get all the money in this case, because she knows Bob's old secret now. Alice's old transaction is therefore worthless for Bob.

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- At any point in time, Alice's and Bob's money is safe. They can send the other's most current transaction to the blockchain at any time to retrieve their money (after 1000 blocks).
- If both agree to close the channel, they can do so using a common 2-of-2-multisig transaction. This means that under normal circumstances, only two "real" Bitcoin transactions are needed, one to open the channel and one to close it in the end.

# Indirect Payments

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- Let us assume that Alice wants to send 1 ₿ to Charlie without first establishing a payment channel with him. Let us further assume that Bob and Charlie possess a payment channel between each other.
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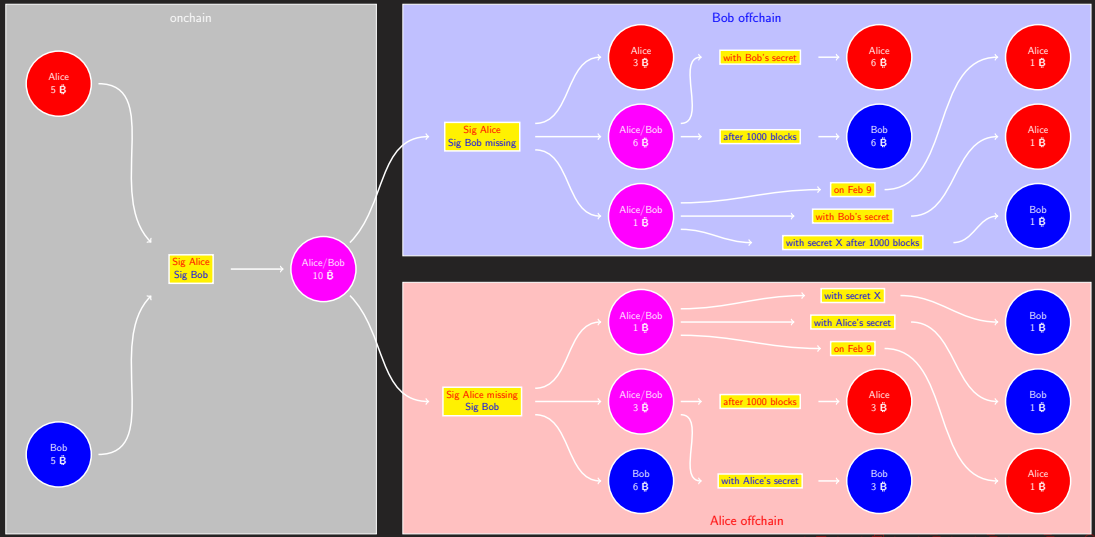
- Alice, Bob and Charlie proceed as follows:
  1. Alice asks Charlie to create a secret X and send her its hash.
  2. Bob uses his channel to Charlie to pay Charlie 1 ₿ in exchange for secret X.
  3. Alice uses her channel to Bob to pay Bob 1 ₿ in exchange for secret X.
  4. Similar to direct payments, steps 2 and 3 will use special Hash Time-Locked Contracts (HTLCs), which will make use of absolute time locks instead of relative ones.

# Hash Time-Locked Contracts — Channel between Alice and Bob



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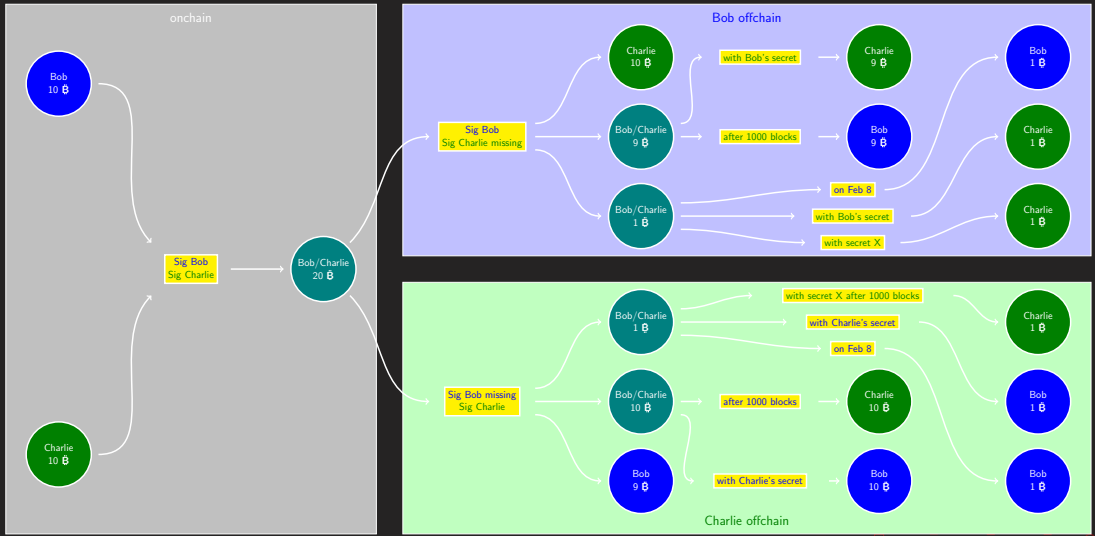
- For the payment of 1 ฿ a new multisig-address is created for both transactions, which can be unlocked in three different ways:
  - If Bob knows secret X and signs, he gets the money. However, he has to wait for 1000 blocks to receive it if he is the one that closes the channel. If he chooses this option, secret X will be publicly visible on the blockchain.
  - Whoever closes the channel gets the money if he or she knows the other's secret. As before, this makes outdated transactions useless.
  - Independent of who closes the channel, Alice can get her money back on February 9.

# Hash Time-Locked Contracts — Channel between Bob and Charlie



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**Remark**

Of course it is possible to do transactions in the same way with more than one intermediary. The only thing to keep in mind is to set the time-lock dates in a way that give parties further down the chain enough time to react.

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**Remark**

As for direct payments, payments using intermediaries normally do not require any transactions to be sent to the blockchain. As long as everybody plays by the rules, everything happens offchain.

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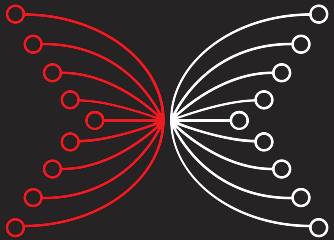
- As long as anybody plays by the rules, only two Bitcoin transactions are necessary per channel, one to open the channel, one to close it again. All other transactions can be processed fast and cheap "offchain".
- Bitcoin guarantess the security of the system: If somebody violates the rules, no honest party loses their money.



INPUT | OUTPUT