Cryptocurrency Engineering and Design

MAS.S62

2/7/2018 Lecture 1

Introduction

- Who we are
  - Neha Narula
  - Tadge Dryja
  - James Lovejoy (TA)
- Digital Currency Initiative
- Course
  - Lectures (20%)
  - Labs (40%)
  - Final project (40%)

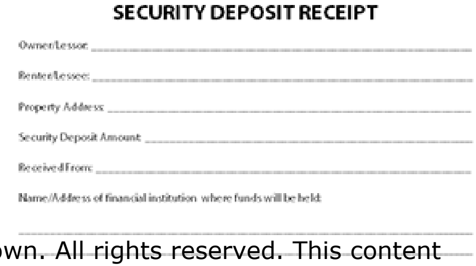
Cryptocurrency Engineering and Design

- What is a cryptocurrency?
- How is it different than a regular currency?
- What does it mean to build one?

What we are not going to do

- How to ICO
- Trading advice
- Permissioned blockchains

Origins of Money


SECURITY DEPOSIT RECEIPT

Owner/Lessor: ____________________

Renter/Lessee: ____________________

Property Address: ____________________

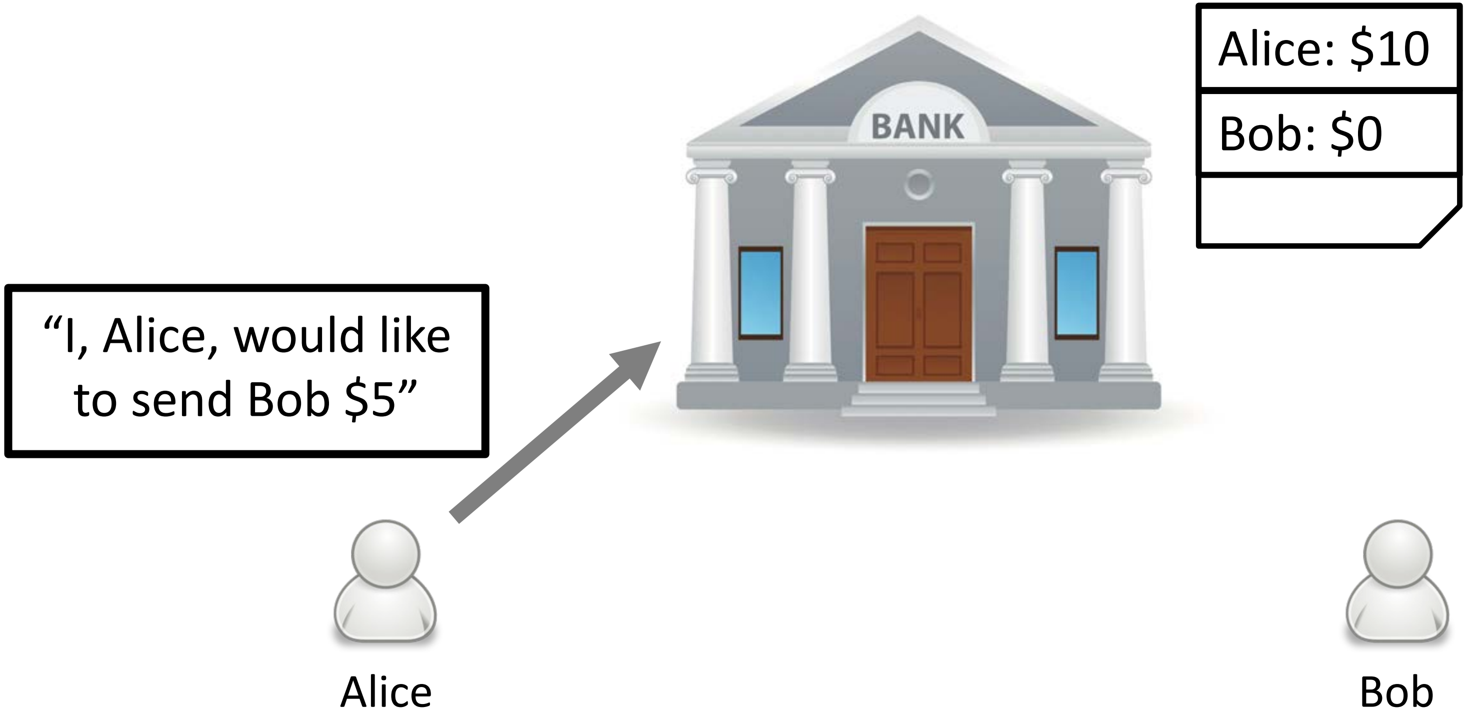
Security Deposit Amount: ____________________

Received From: ____________________

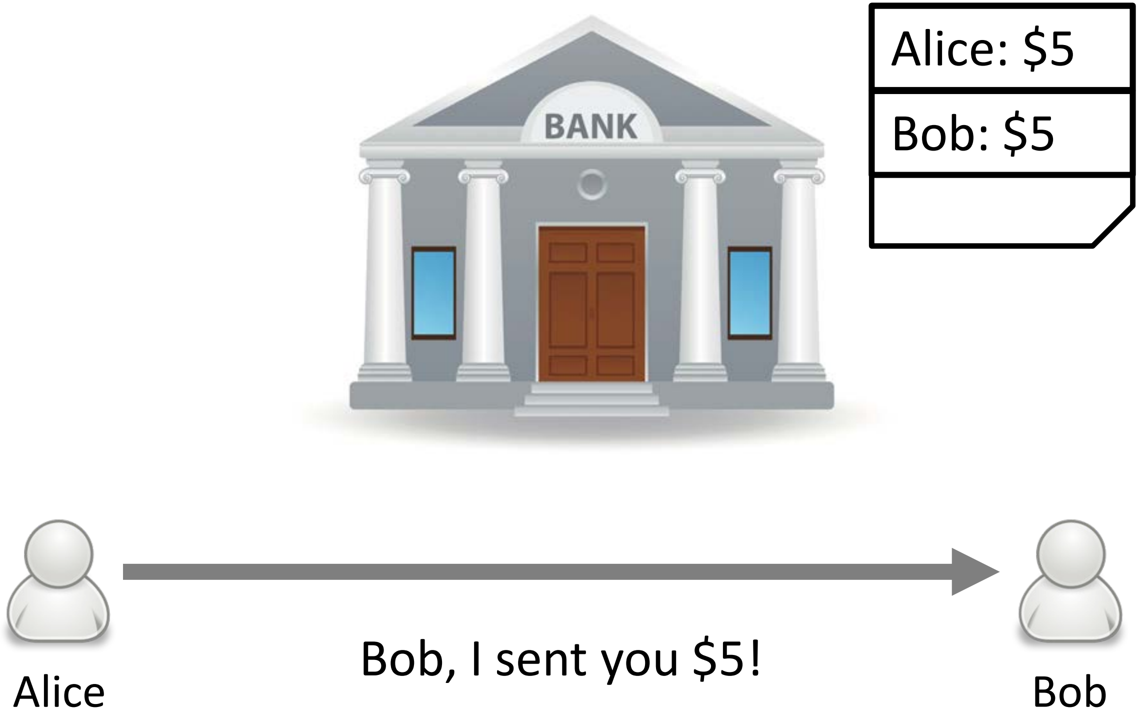
Name/Address of financial institution where funds will be held:

____

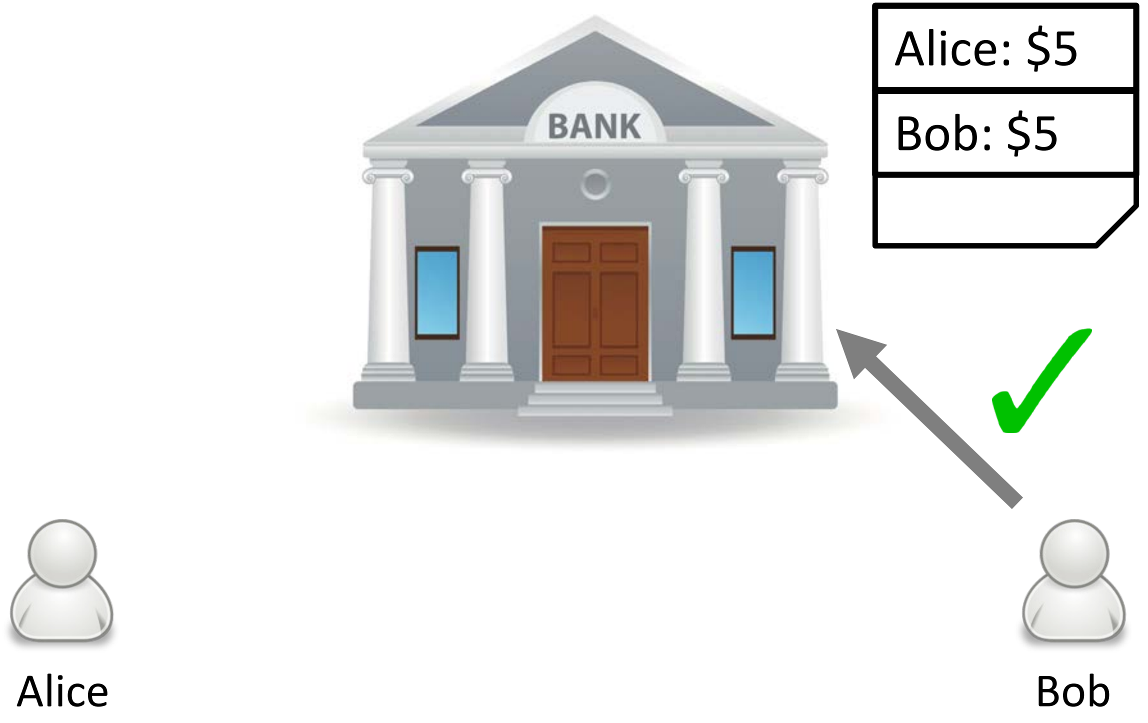
Traditional payments



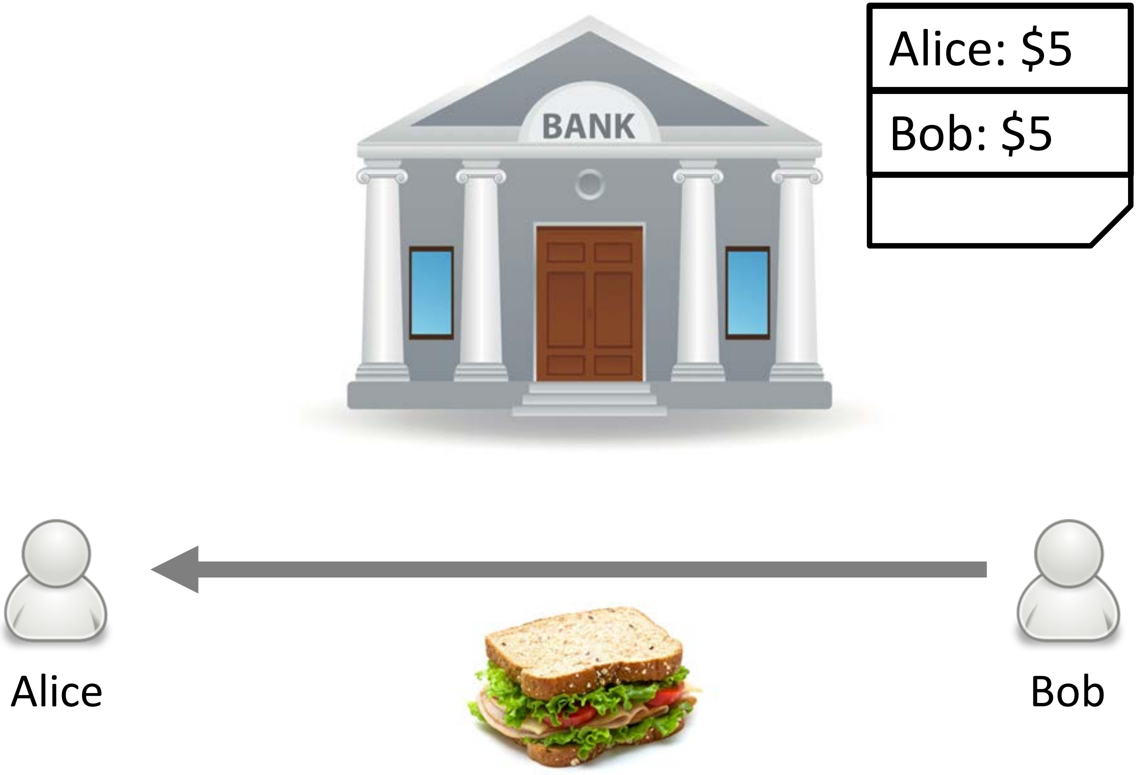
Traditional payments



Traditional payments



Traditional payments



Pros/cons of banks

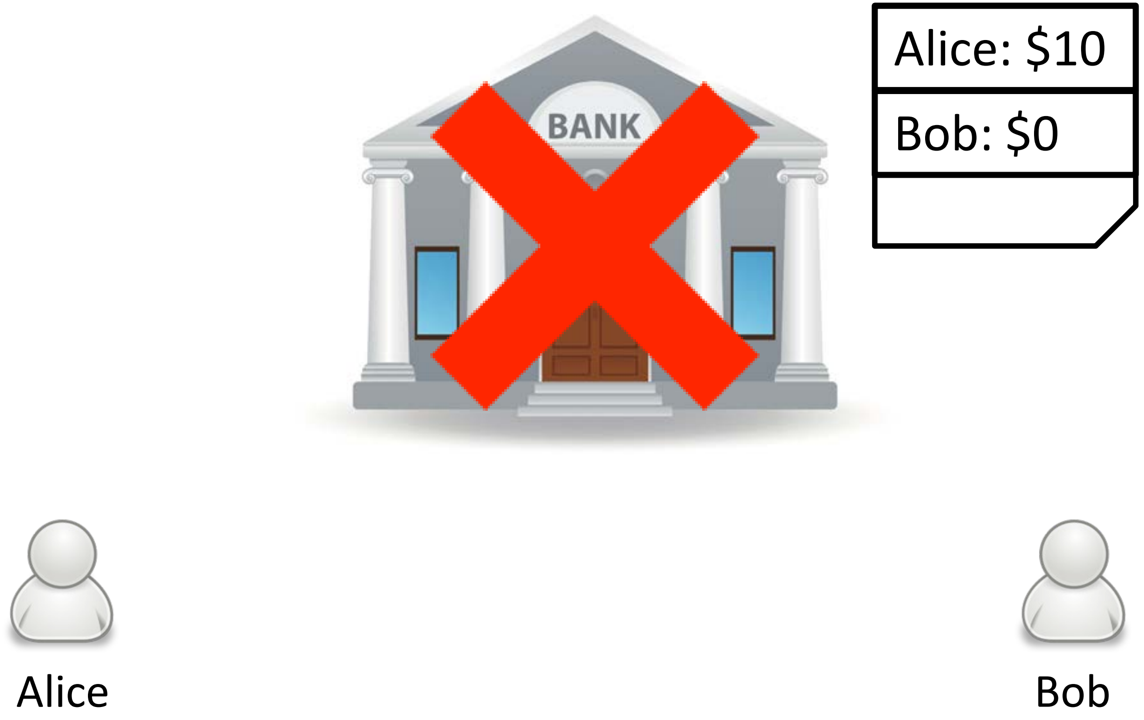
Pros

- Digital payments

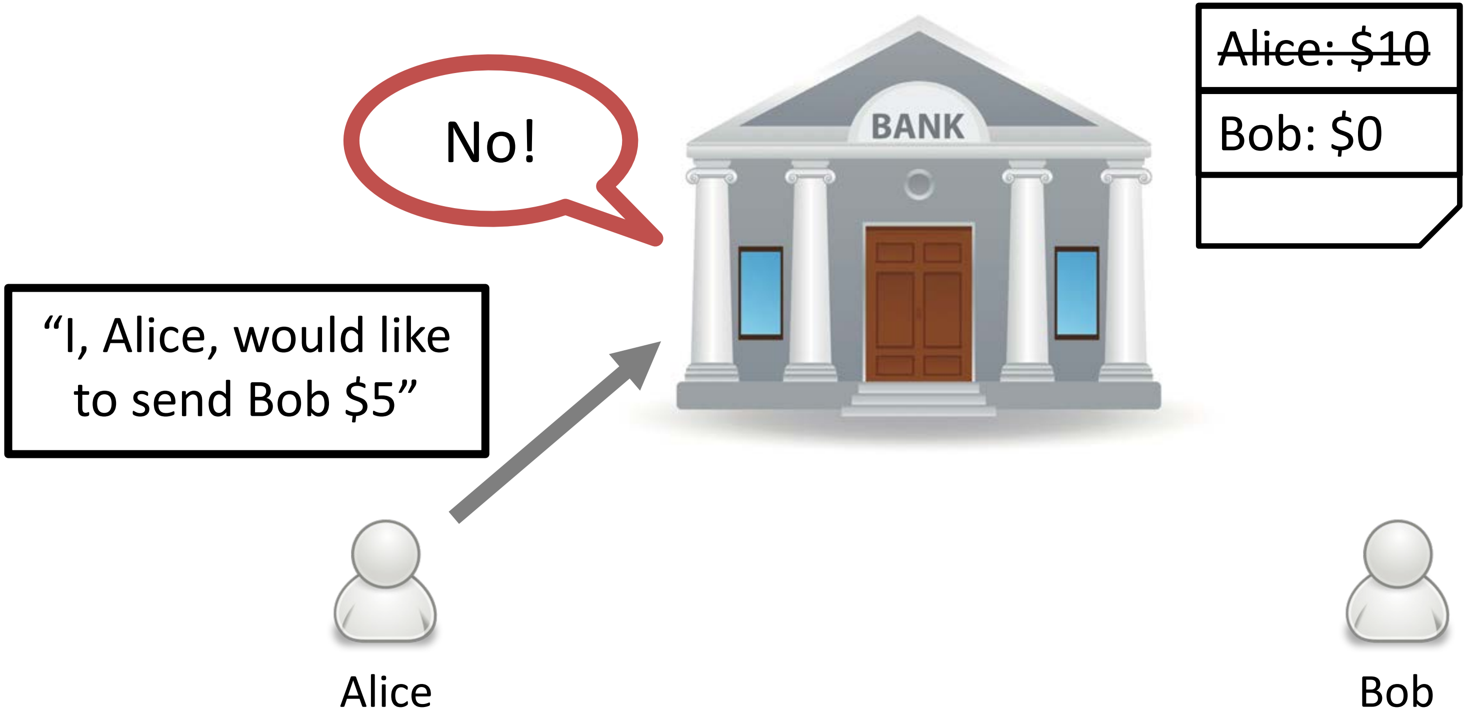
Cons

- Not peer-to-peer (bank must be online during every transaction)
- Bank can fail
- Bank can delay or censor transactions
- Privacy

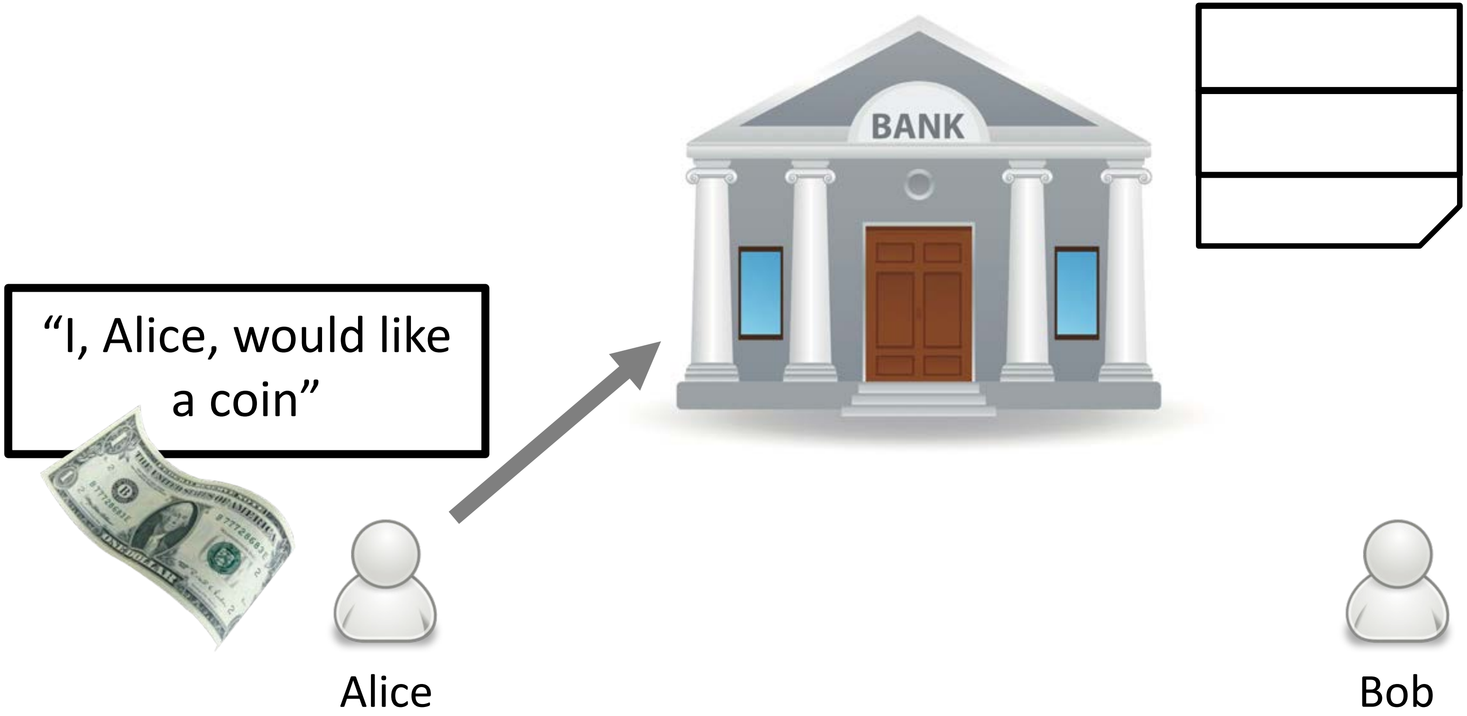
The bank can fail



The bank can delay or censor

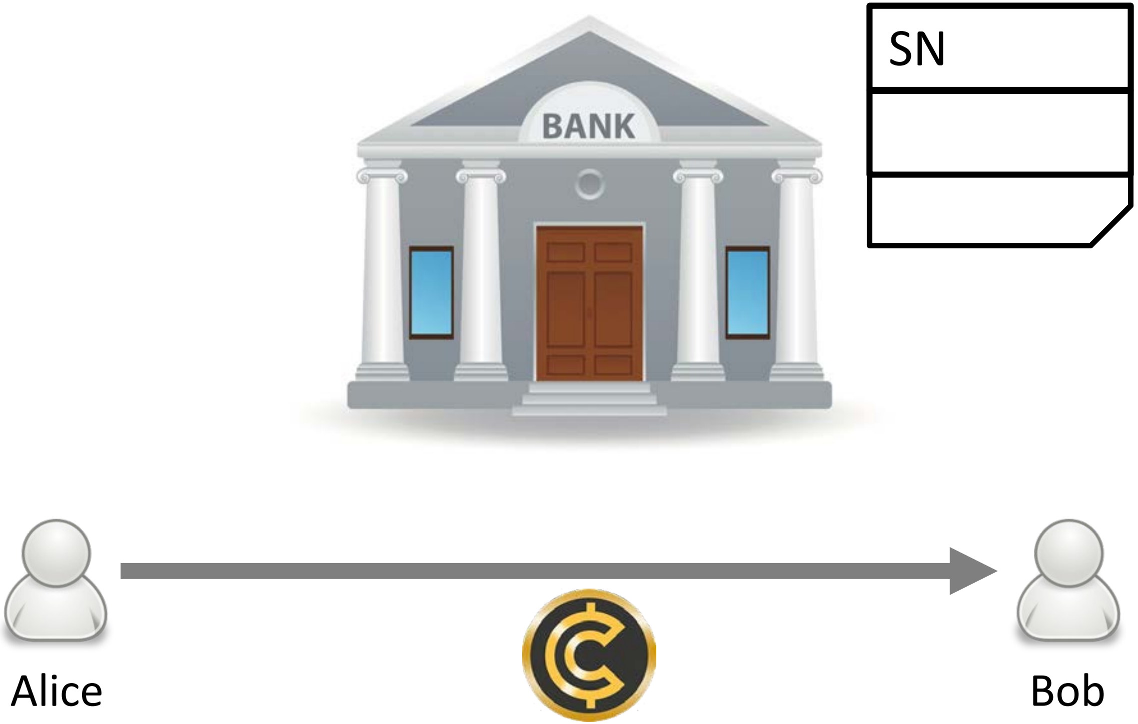


E-cash

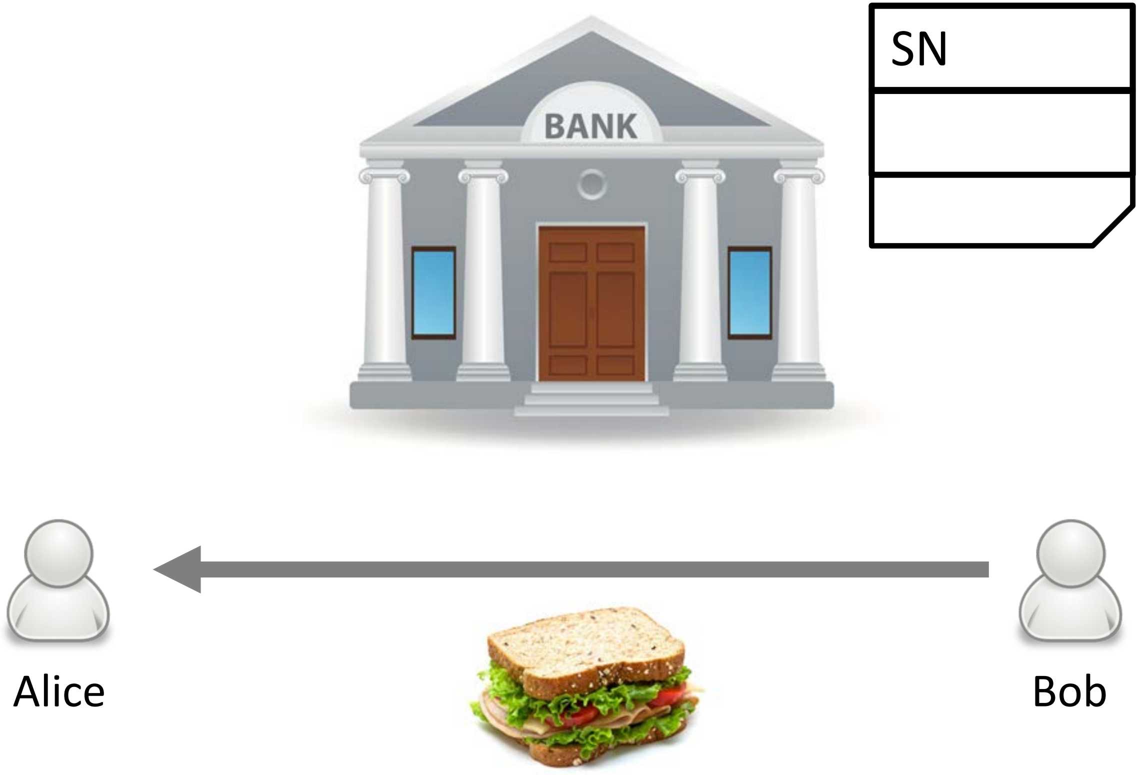


E-cash

E-cash

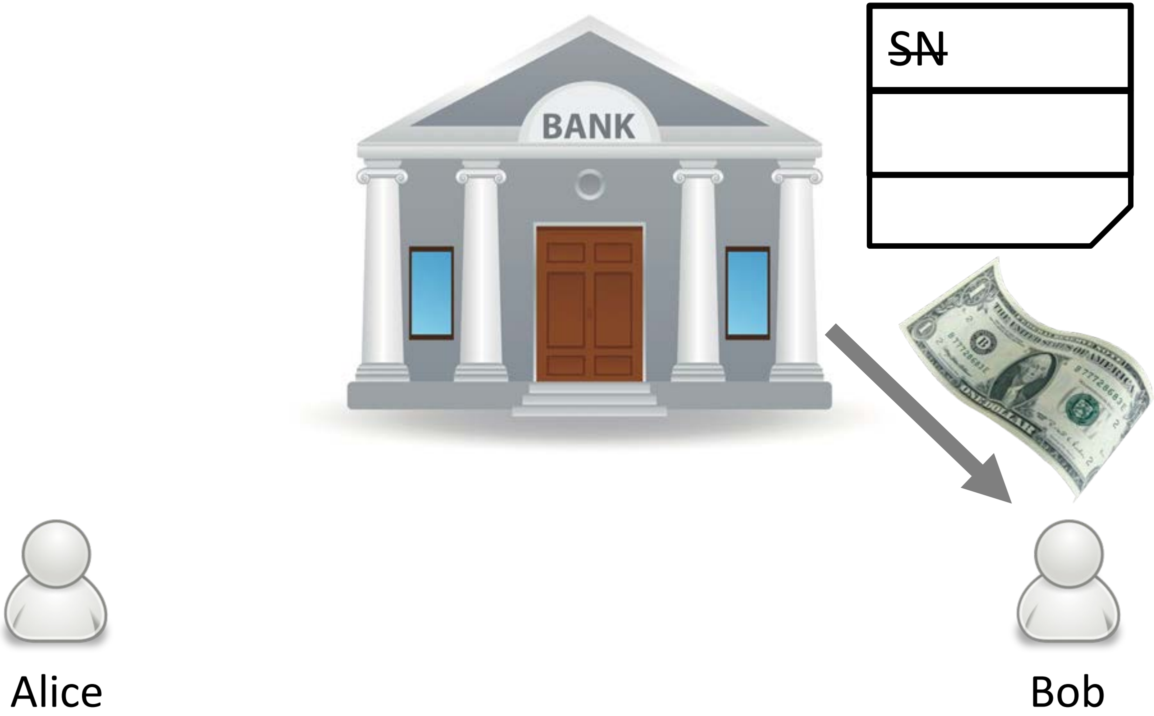


E-cash



E-cash

E-cash



Pros/cons of simple e-cash

Pros

- Digital payments
- Peer-to-peer

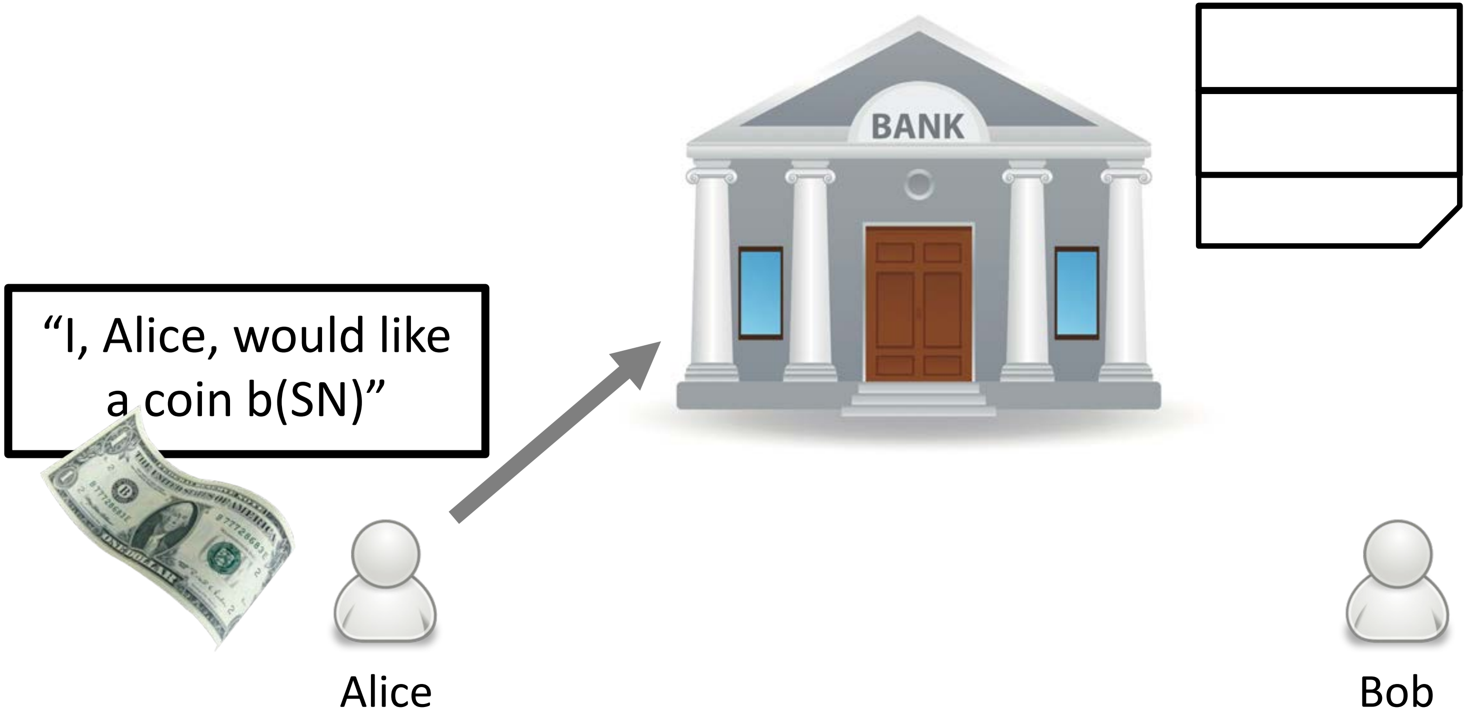
Cons

- Bank needs to be online to verify
- Bank can fail
- Bank can delay or censor transactions
- Privacy

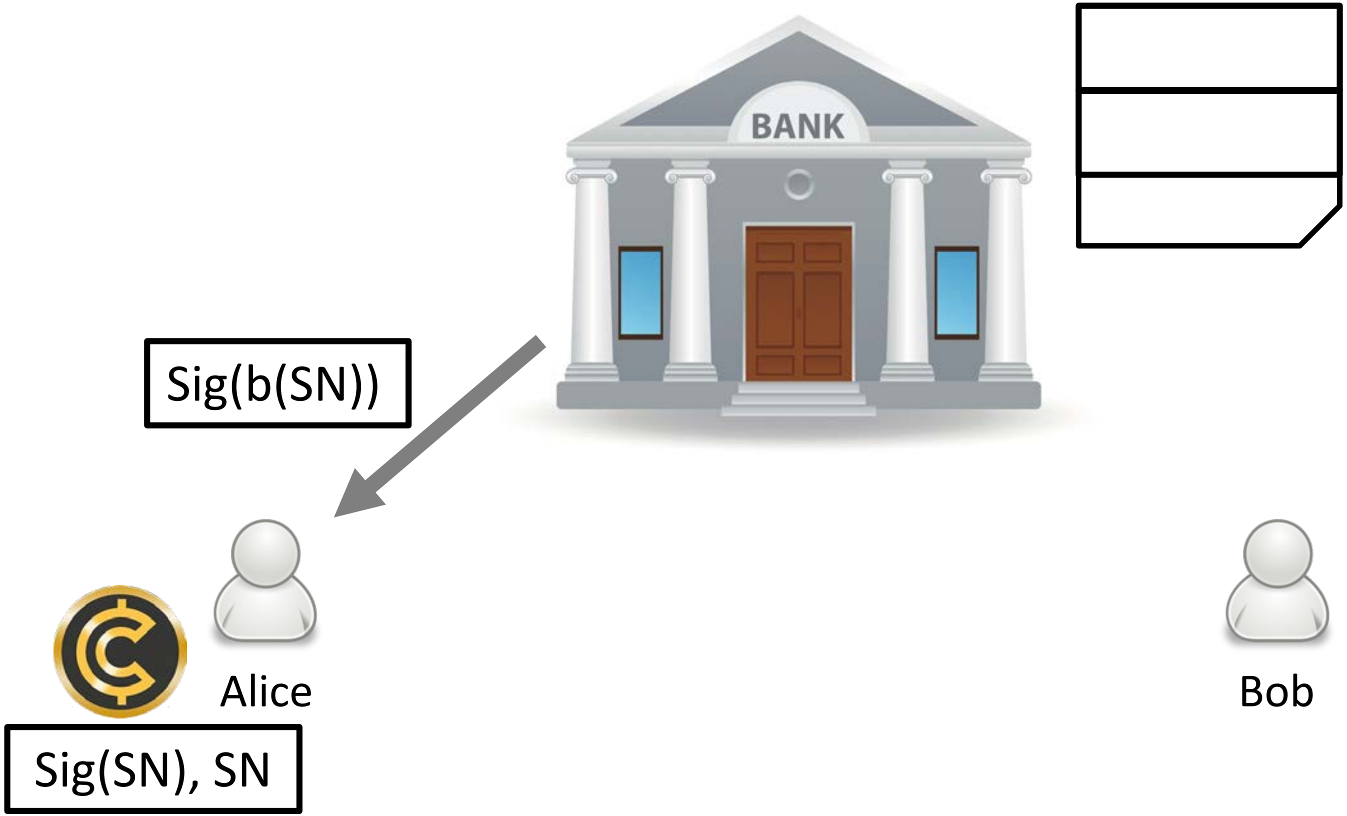
Chaumian e-cash

- Alice can choose SN
- Alice “blinds” her message to the bank so bank can’t see SN
- When Bob redeems, bank doesn’t know payment came from Alice

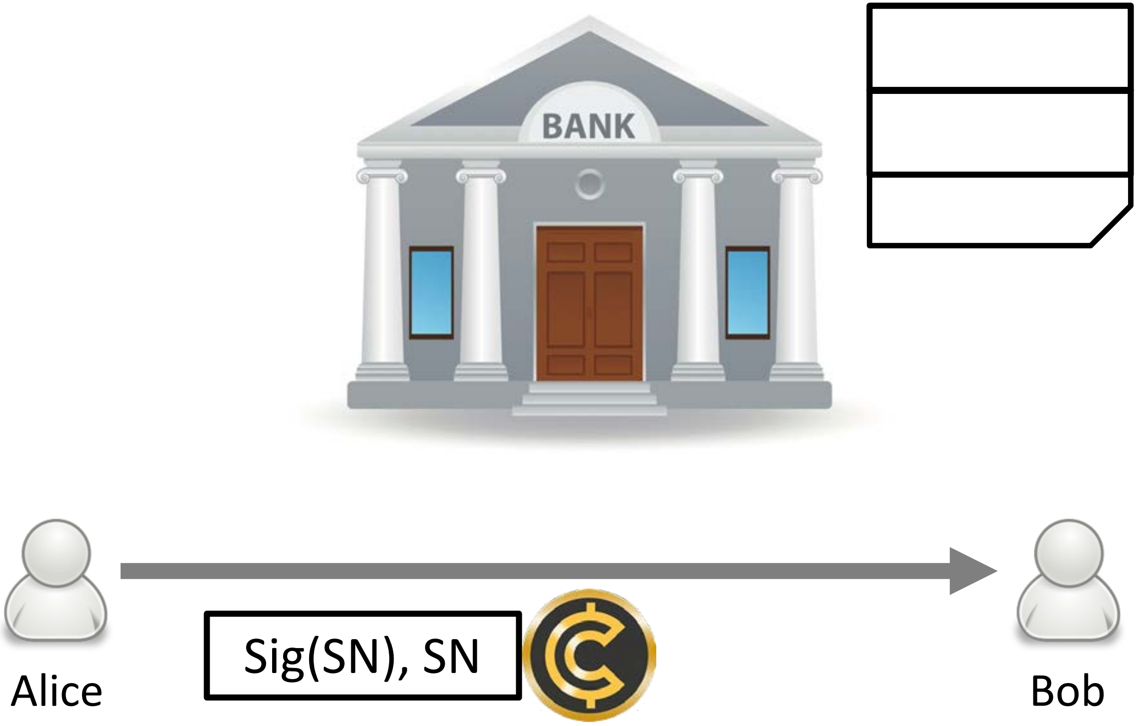
Chaumian e-cash



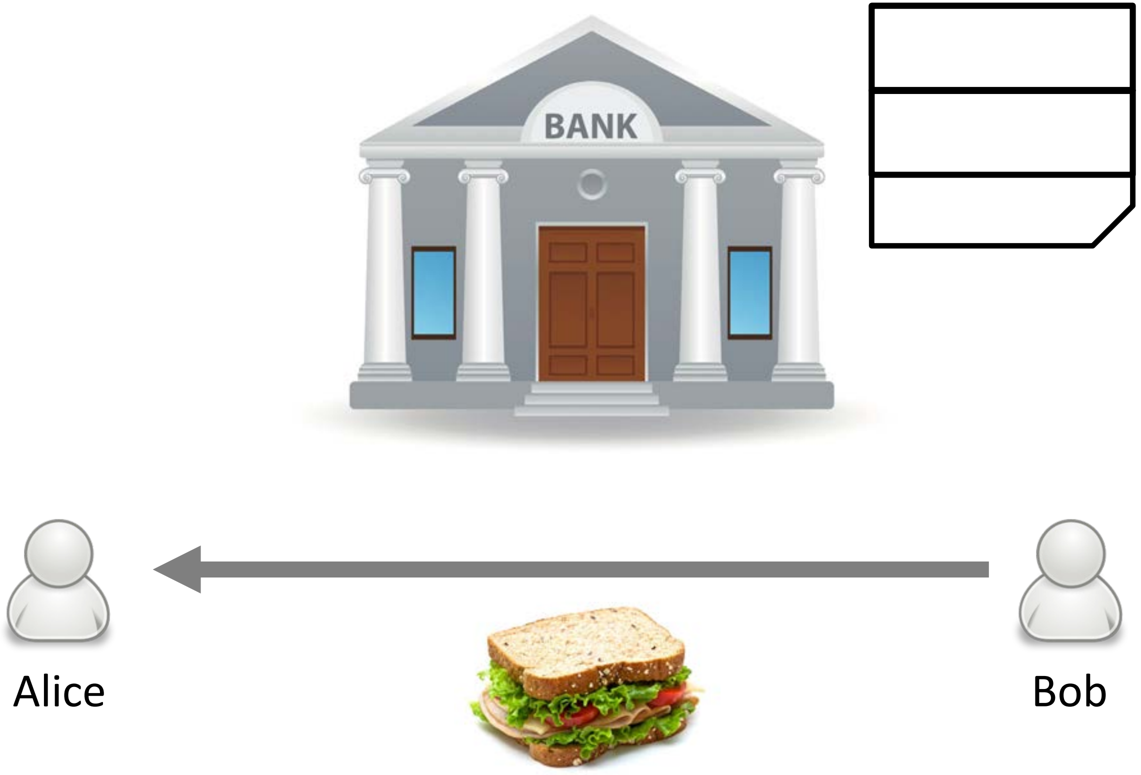
Chaumian e-cash



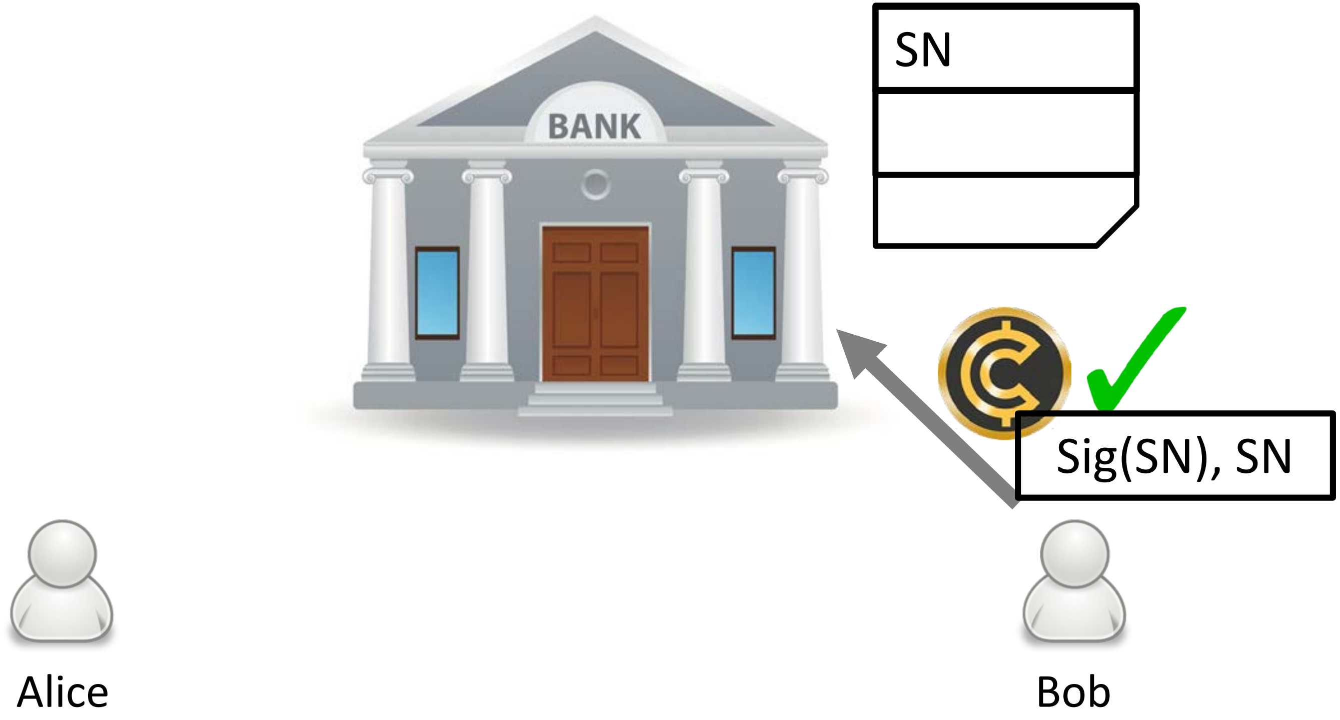
Chaumian e-cash



Chaumian e-cash



Chaumian e-cash



Double spend detection

Pros/cons of Chaumian e-cash

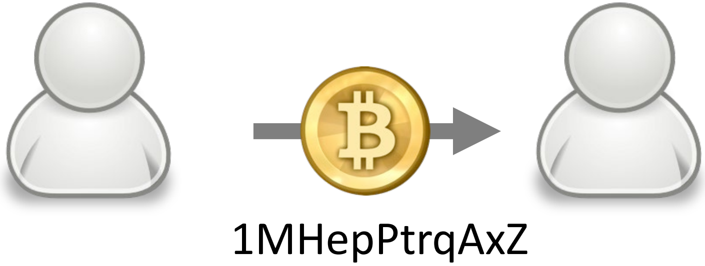
Pros

- Digital payments
- Peer-to-peer
- Privacy
- Offline double-spend detection

Cons

- Bank can censor withdrawals and deposits

How to build decentralized digital token transfer?



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lecture 1

2018-02-07

Neha Narula & Tadge Dryja

Primitives for making a cryptocurrency

Hash functions

Signatures

Hash functions

Simple, right? But powerful.

hash(data) -> output

data can be any size; output is fixed size

Hash functions

Important. You can do everything* with just hash functions.

*can't do some fun stuff with keys

(Key exchange, signature aggregation, etc)

Hash functions

Any size input, fixed output… output is “random” looking

What’s that mean? Deterministic, no randomness

But the outputs look like noise; half the bits are 1s, half are 0s

Hash functions

Somewhat more well defined -

“Avalanche effect”: change 1 bit of the input, about half the output bits should change

Hash functions

Well defined: what it shouldn't do

preimage resistance

(2nd preimage resistance)

collision resistance

preimage resistance

given y, you can't find any x such that hash(x) == y

(you can find it eventually, but that will take 2^{256} operations (10^{78}))

2nd preimage resistance

given x, y, such that hash(x) == y,
you can’t find x’ where

x’ != x

and hash(x’) == y

(this one is a bit of a mess so lets leave it at that)

collision resistance

nobody can find any x, z such that

x != z

hash(x) == hash(z)

(again, you can find them eventually. And in this case, not 2^{256})

resistances

Practically speaking, collision resistance is “harder”;

collision resistance is broken while preimage resistance remains

Examples: sha-1, md5

usages

hashes are names

hashes are references

hashes are pointers

hashes are commitments

Commit reveal

Commit to something secret by publishing a hash

Reveal the preimage later.

Example: `a1c089bf65e852cf2ba2010d2ba84e2025ec937b5f8b9dac682c35dcf498aef4`

Commit reveal

a1c089bf65e852cf2ba2010d2ba84e2025ec937b5f8b9dac682c35dcf498aef4

Reveal:

I think it won't snow Wednesday! d79fe819

```
$ echo "I think it won't snow Wednesday! d79fe819" | sha256sum

a1c089bf65e852cf2ba2010d2ba84e2025ec937b5f8b9dac682c35dcf498aef4  -
```

Commit reveal

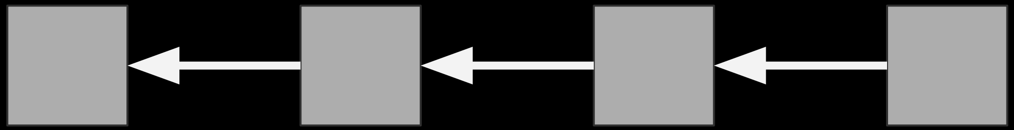
```
$ echo "I think it won't snow Wednesday! d79fe819" | sha256sum

a1c089bf65e852cf2ba2010d2ba84e2025ec937b5f8b9dac682c35dcf498aef4  -
```

Add randomness so people can’t guess my preimage; HMAC

This is a kind of proto-signature

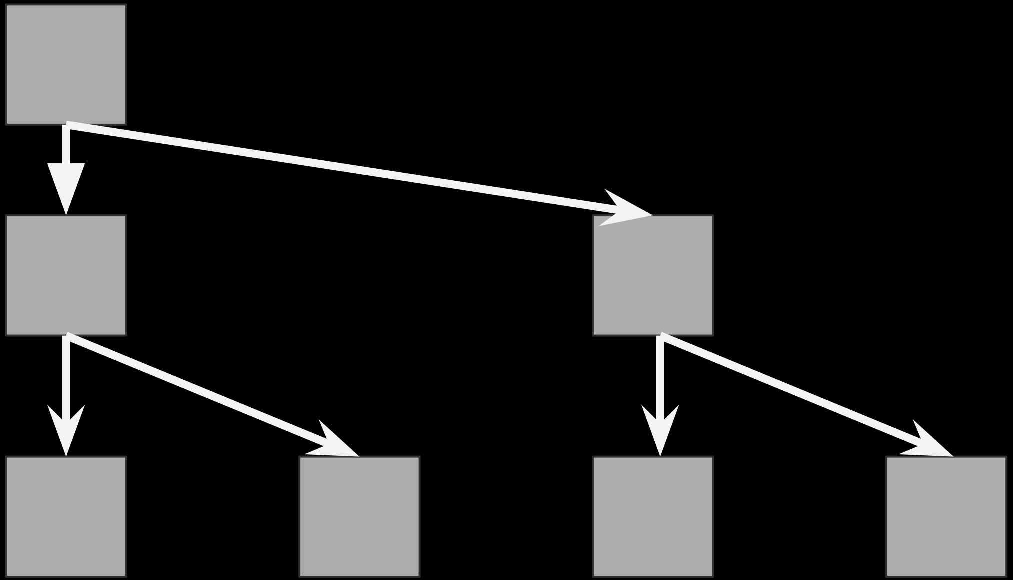
Linked list with hashes



We could call this a “hash-chain”

Also, it’s basically git

Binary tree with hashes



How can 2 inputs go to 1 output?
Not a collision. Concatenate then hash: h(a,b)

What’s a signature?

Signatures are useful! Messages from someone. 3 functions needed:

GenerateKeys()

Sign(secretKey, message)

Verify(publicKey, message, signature)

3 functions

GenerateKeys()

Returns a privateKey, publicKey pair

Takes in only randomness

3 functions

Sign(secretKey, message)

Signs a message given a secretKey.

Returns a signature.

3 functions

Verify(publicKey, message, signature)

Verify a signature on a message from a public key. Returns a boolean whether it worked or not.

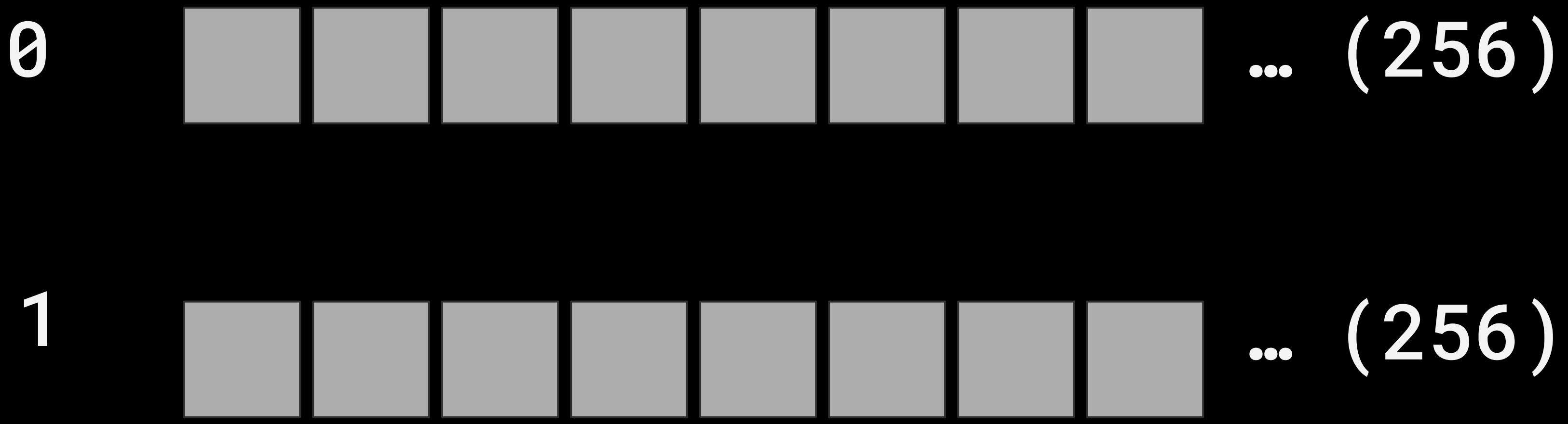
Signatures from hashes

It’s doable! In fact, you’ll do it!

First pset is to implement a signature system using only hashes.

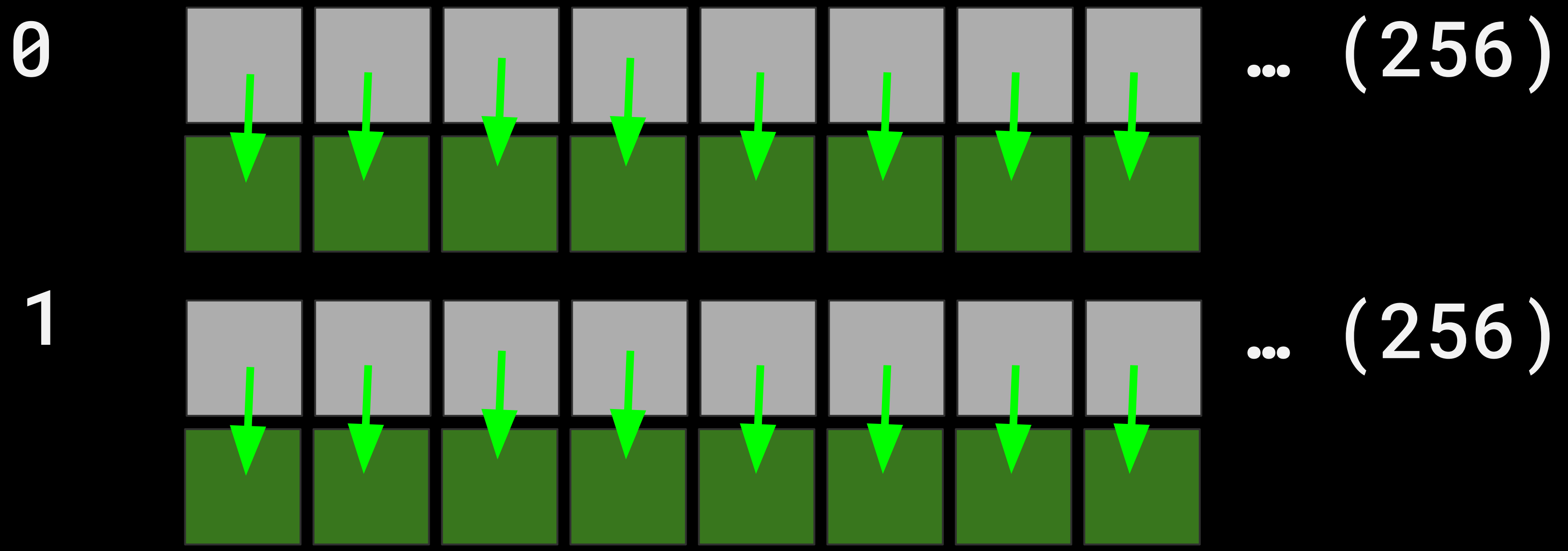
This is called “Lamport Signatures”

Lamport Sigs: Generate key



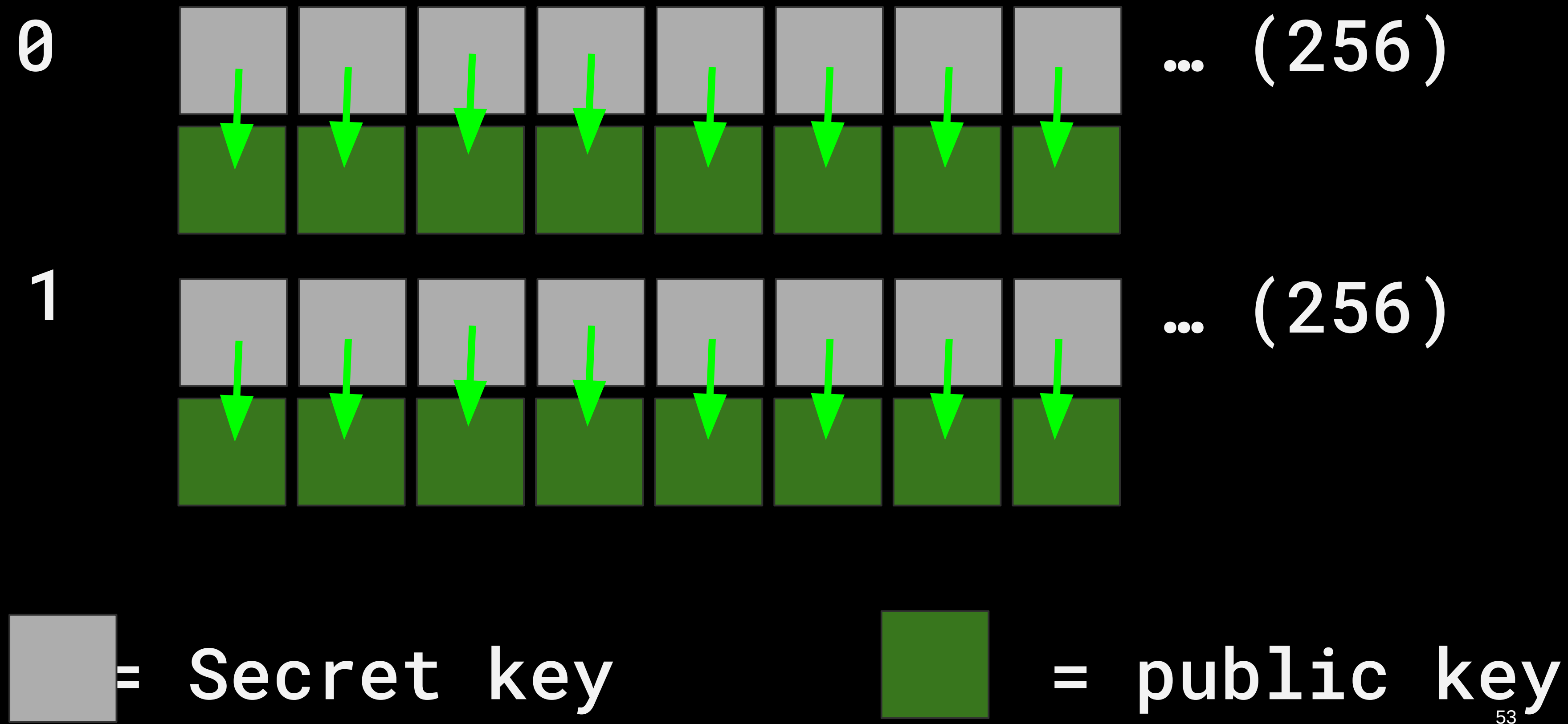
Make up 256*2 random 256 bit numbers

Lamport Sigs: Generate key



Get hashes for each

Lamport Sigs: Generate key

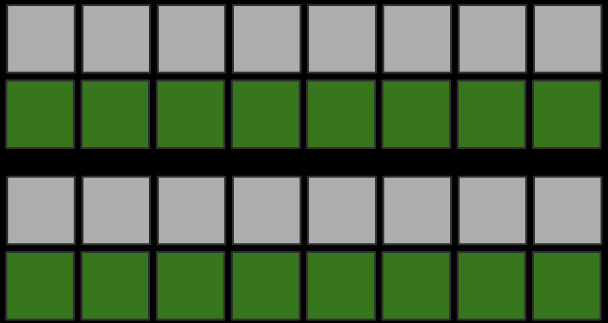


Lamport Sigs: Sign

Hash string to sign.

“Hi” = 8f434346648f6b96df89dda901c5176b10a6d83961dd3c1ac88b59b2dc327aa4

Pick private key blocks to reveal based on bits of message to sign



Lamport Sigs: Sign

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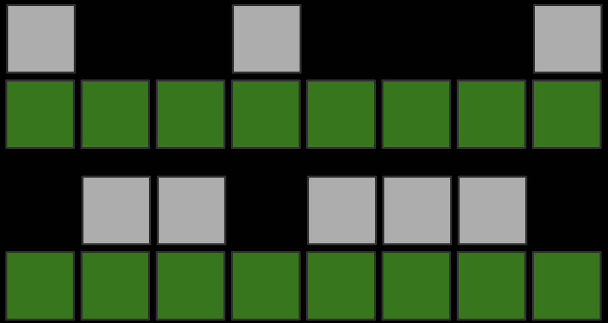
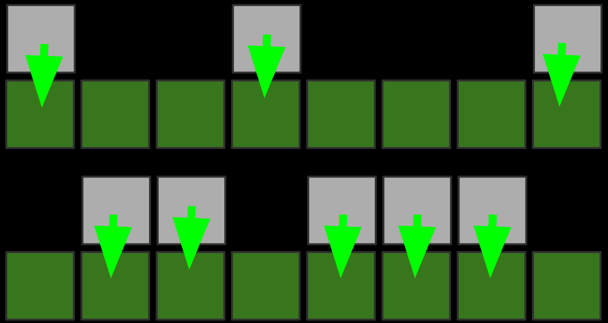
01101110



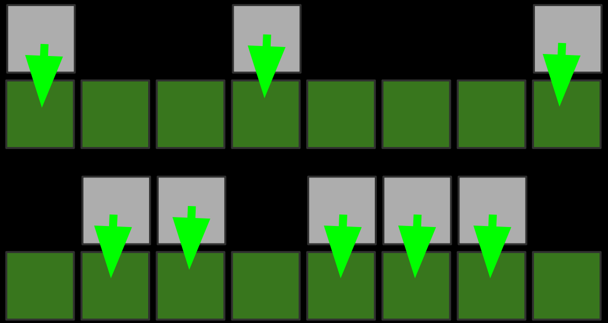
Lamport Sigs: Verify

Hash each block of the signature
Verify that it turns into the block of the public key



Lamport Sigs: Signing again

Signing more than once reveals more pieces of the private key



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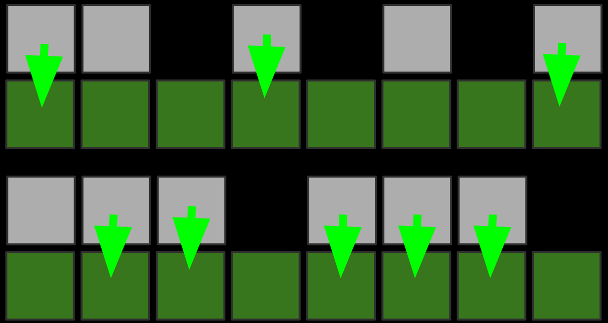

Lamport Sigs: Signing again

1 sig: can’t forge anything
2 sigs: ~½ bits constrained
3 sigs: ~¼ bits constrained

pset01: Lamport signatures

In golang
On github
Most of the signing code is written
Tests implemented
Also public key with 4 signatures;
try to forge another!
Office hours / messages on slack