An Introduction to Bitcoin

BILL LABOON (LABOON@CS.PITT.EDU)

LECTURER, COMPUTER SCIENCE DEPARTMENT, UNIVERSITY OF PITTSBURGH

What is Bitcoin?

- A peer-to-peer, electronic cash system…
- which creates a cryptographically secure distributed ledger (*the blockchain*)…
- and secures it with *proof-of-work*…
- to enable *pseudonymous* transactions in a *decentralized* manner (with no controlling body or regulator).
- As of today, it is by far the most successful *cryptocurrency*.

Created in 2009 by “Satoshi Nakomoto”

- A pseudonym - to this day, nobody knows who he/she/they is/are
- There had already been numerous failed attempts at creating a “cryptocurrency”…

Announcing the first release of Bitcoin, a new electronic cash system that uses a peer-to-peer network to prevent double-spending. It's completely decentralized with no server or central authority.

See bitcoin.org for screenshots.

Download link:
http://downloads.sourceforge.net/bitcoin/bitcoin-0.1.0.rar

Windows only for now. Open source C++ code is included.

- Unpack the files into a directory
- Run BITCOIN.EXE
- It automatically connects to other nodes

The User's Perspective

- This presentation will explain HOW Bitcoin works…
- … but it is not necessary to know these details to use it.
- You can check your email without understanding (or knowing about!) TCP/IP, caching algorithms, or CPU process scheduling.
- At a high level, Bitcoin network consists of addresses and keys to those addresses

Wallet (Address and Key)

Bitcoin Address

SHARE

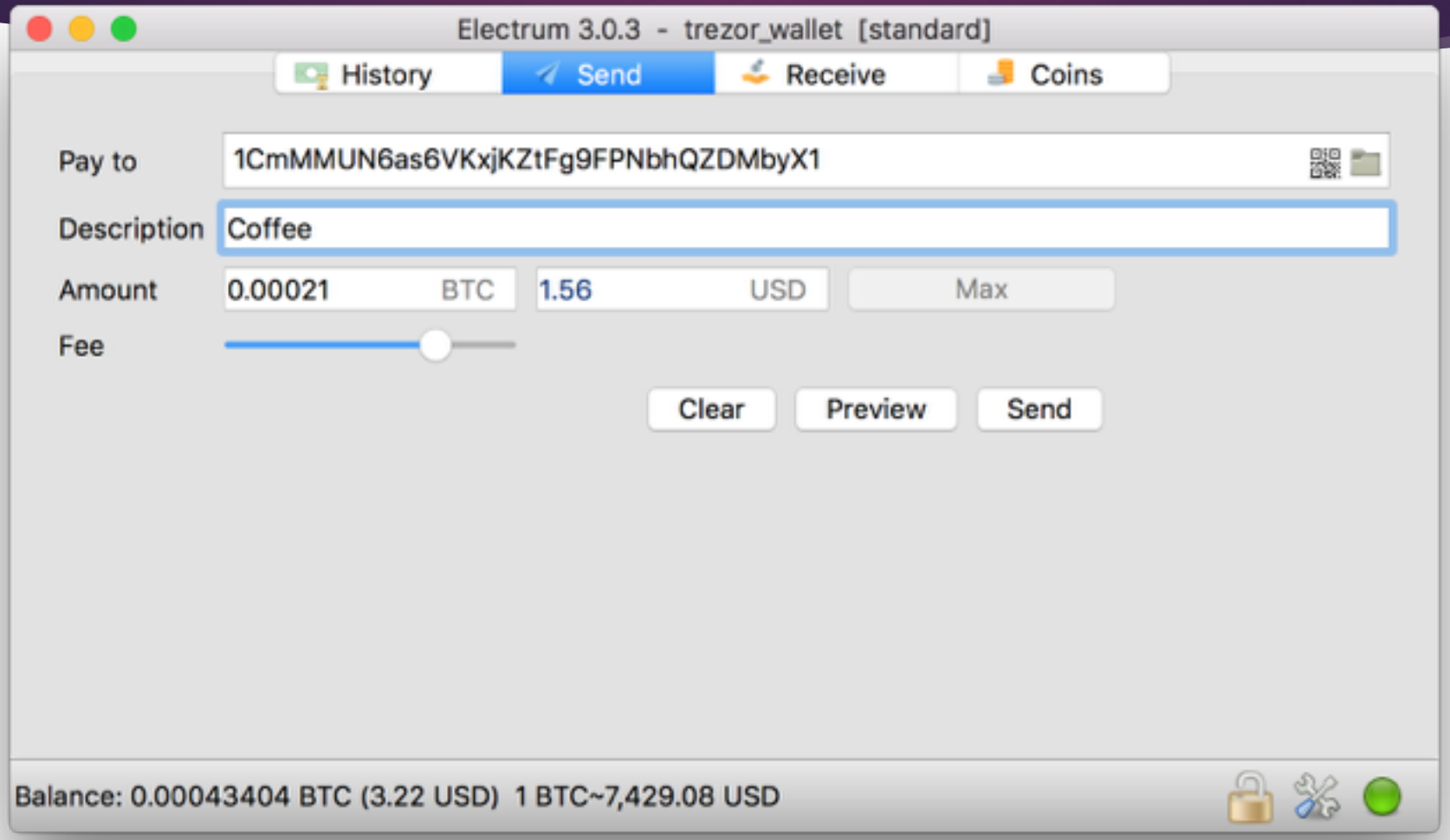
`1CmMMUN6as6VKxjKZtFg9FPNbhQZDMbyX1`

Private Key

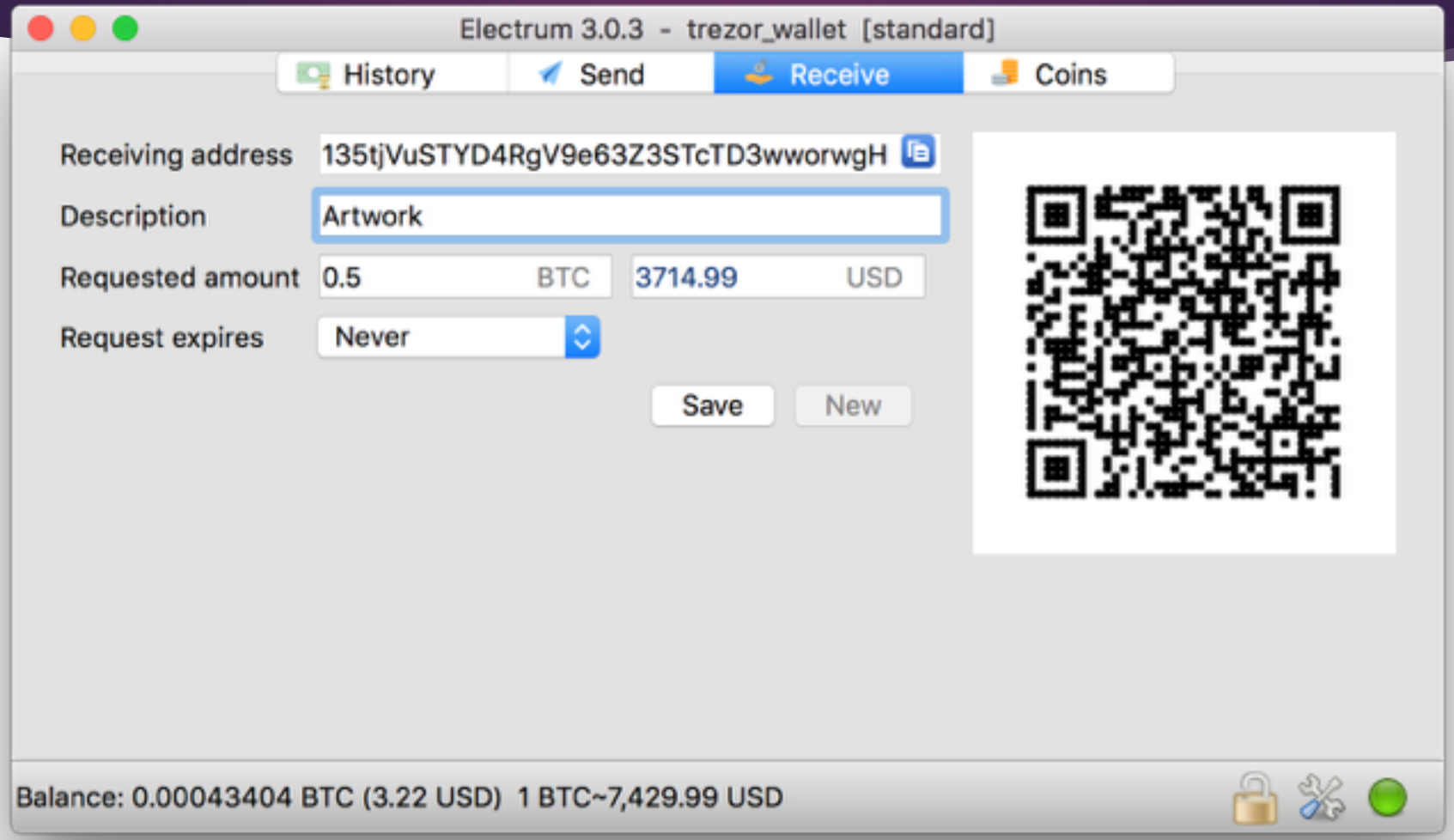
SECRET

`KyxgwmqzCiUQ1NvUZkQKet56rgwwuNZda8QChFV3DLEp9EVj54rB`

Sending Bitcoin



Receiving Bitcoin



How do you get bitcoin?

- **Mining:**
  - Creating Bitcoin by securing the network (discussed later - rarely done by individuals nowadays)
- **From another person -**
  - Convince someone who has bitcoin to give you some
- **From an exchange -**
  - By far the most common way
  - Just like trading currency (e.g. exchanging dollars for euros)
  - Numerous exchanges - Coinbase, Poloniex, Kraken

What is a bitcoin?

- Think if someone came into a bank and asked to see "their" dollar bills in their checking account
- Bitcoin is an abstraction - there is no such thing as a "physical bitcoin" or "a bitcoin on the network"
- A bitcoin is just an arbitrary division - 1 / 21 millionth of all the value on the Bitcoin network
- Smallest unit is a satoshi - there are 100 million satoshi in one bitcoin (= 2.1 quadrillion satoshi in Bitcoin network)

Bitcoin: A VERY Large Mail Room

1890112 3987254 2219071 7653421	99325231 80031287 81652837 98117262	97272727 98172652 88291542 22873651	65245567 90233746 00018276 91356483	83822733 89192635 11273525 33345981
7652352 8272636 9013463 8827345	77615343 66253411 98165473 00110872	43447691 00928371 01827777 82337257	88272633 91023932 99847574 99283644	86374561 10928373 77253526 99283731
8190292 9827362 3354677 8892837	72636451 91802927 29384761 83873647	01893820 29387271 99827326 44563289	10293833 29299384 00938272 99283762	67182001 22283736 99287362 99022837

Bitcoin: A VERY Large Mail Room

As long as I know the *Bitcoin address*, I can always insert money into the slot.

But I can't get it out without my *private key*.

A Bitcoin address plus a private key is a *wallet*.

86374561
10928373
77253526
99283731

You share your address but never your private key!

Shared “mailroom”

- A copy of this “mailroom” is (in a manner of speaking) on every Bitcoin node in the network
- An alternative way to think about this is that every Bitcoin node has a spreadsheet which lists every transaction ever made on the Bitcoin network
- But this is a special spreadsheet where I can only move bitcoin from an address if I know the corresponding secret key

How Do I Prevent Others From Moving My Bitcoin?

- We need to take a short detour into one-way functions here…
- A one-way function is simple to do in one direction, but much more difficult going "backwards"
- By-hand example:
  - What is 3.5 to the 4th power?
  - What is the 4th root of 231.3441?

One-Way Functions

- What is 3.5 to the 4th power?
  - Relatively simple to do!
  - 3.5 * 3.5 * 3.5 * 3.5 = 150.0625
- What is the 4th root of 231.3441?
  - Much more difficult - but what if I told you the answer was 3.9?
  - Extremely hard to calculate, but relatively easy to verify!
  - 3.9 * 3.9 * 3.9 * 3.9 = 231.3441
- The math problems in Bitcoin follow the same idea but MUCH more complex

Accessing Your Wallet

- Think of your wallet address as “231.3441” and your private key as “3.9”
- Anyone can send to “231.3441” but only you have the power to send from that address, since you know the answer to the math problem (key)

Much more complex

Bitcoin Address

SHARE

1FNQ2uHHpjbhm33NQTRGZUBhsoavWQj9z7

Private Key

SECRET

L11EpZk2v1LJ6JCJTxxcSmm2WsAfbW51rPZdd1ebX4HimM97d1VZ

- **SHARE (Address):**
  3,864,735,657,839,164,620,170,223,983,342,970,231,793,944,167,574,307,629,040
- **SECRET (Key):**
  16,352,452,327,361,720,873,228,280,772,068,220,842,709,704,046,398,069,492,223,434,257,762,933,086,993,622,020,815,355,768

Couldn’t someone just guess your secret key?

- Assume you know the address, you want the secret key
- There is an attempt at something similar, the Large Bitcoin Collider, which checks ~ 4,000,000,000,000 keys per year - let’s say that we have a system that can do that every second
- Do this for 13.7 billion years (432,342,079,200,000,000 seconds - time since the Big Bang)

Couldn’t someone just guess your secret key?

Congratulations, you have a:

0.000000005%

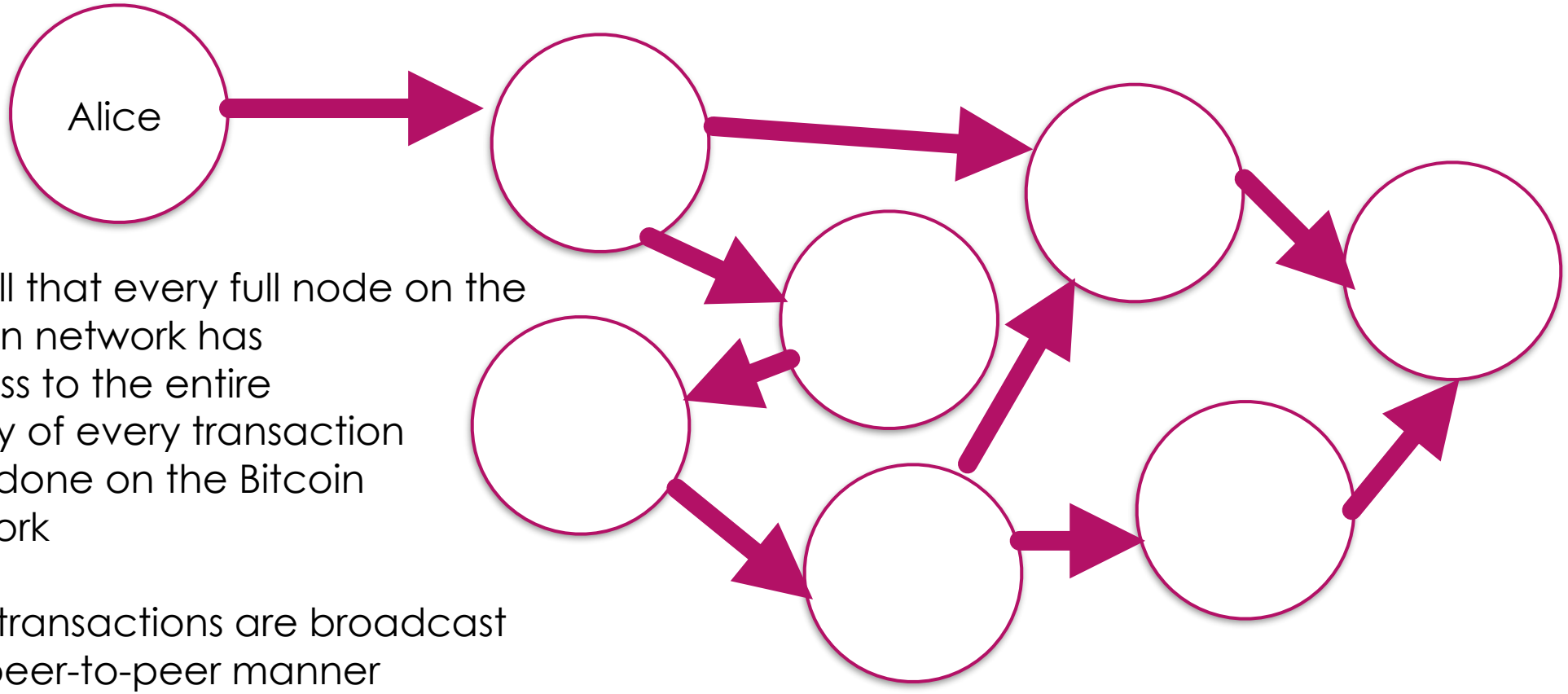
chance of getting the key!

That’s about a 1 in 111 million shot…

Game Theory

- With that much computing power, you'd make much more money just mining (or using it for something else)
- Bitcoin relies on the fact that for a given actor, it almost always makes sense to "play by the rules"
- Note that this does not preclude actors for whom money is not a primary concern!

Distributed Consensus

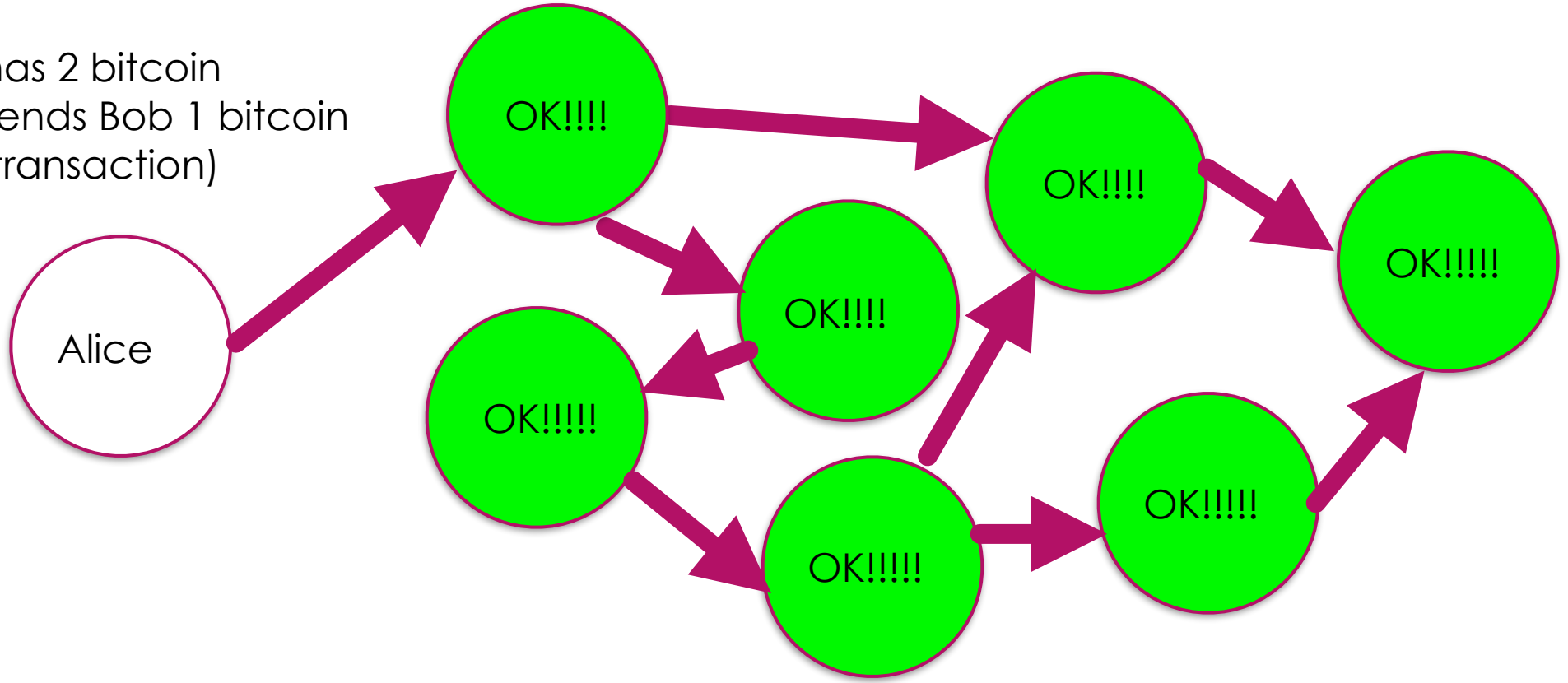


Recall that every full node on the Bitcoin network has access to the entire history of every transaction ever done on the Bitcoin network

New transactions are broadcast in a peer-to-peer manner

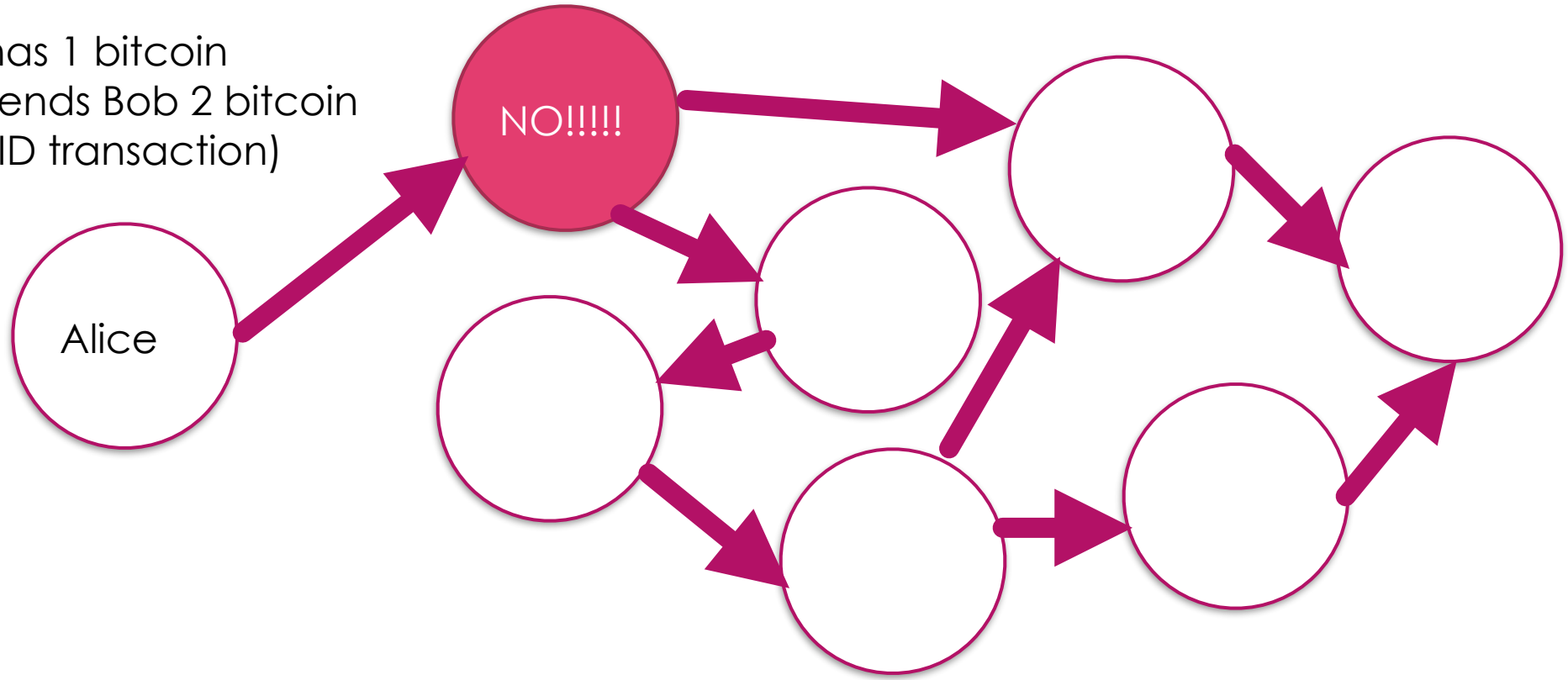
Distributed Consensus

Alice has 2 bitcoin
Alice sends Bob 1 bitcoin
(valid transaction)



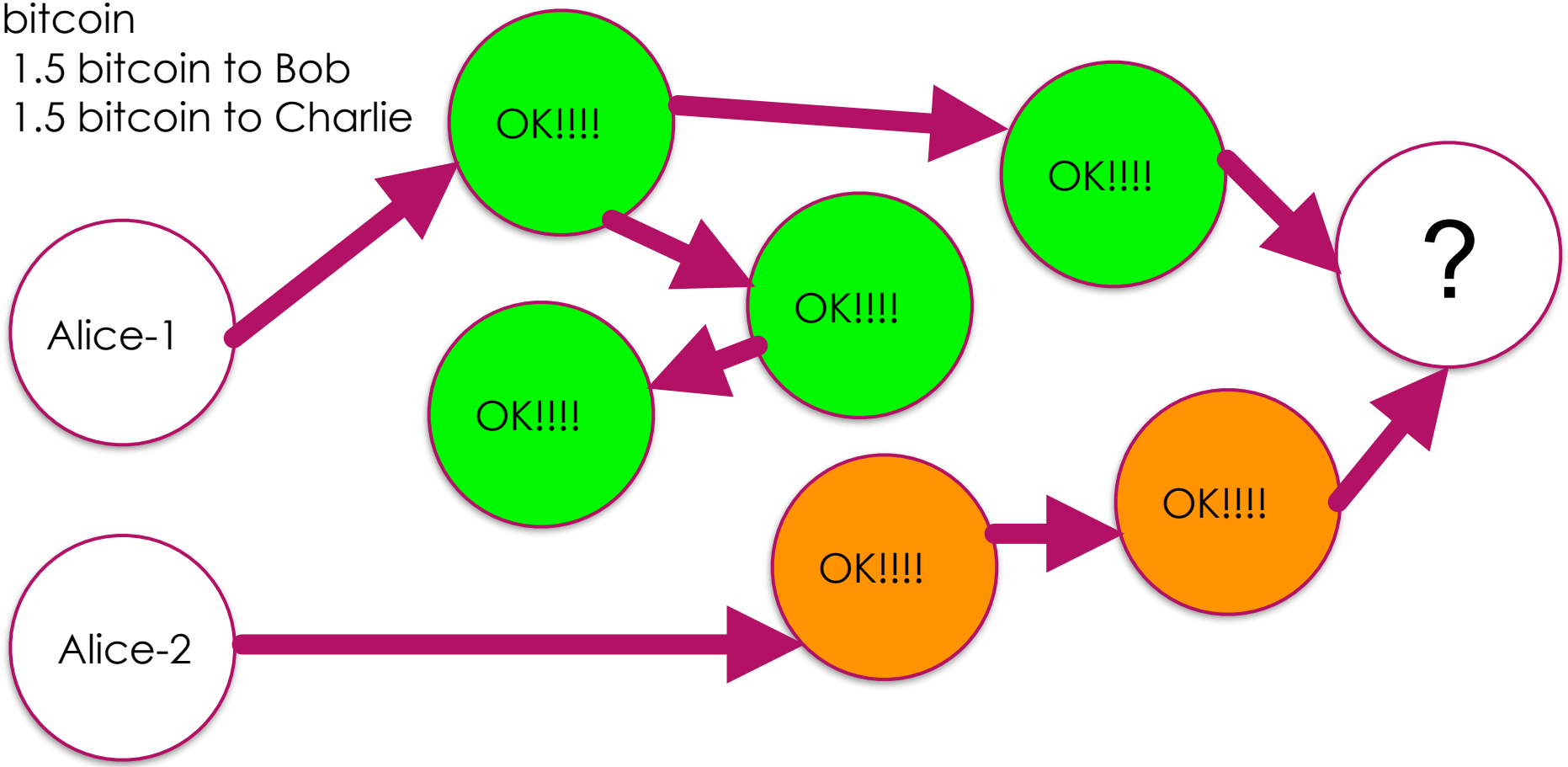
Distributed Consensus

Alice has 1 bitcoin
Alice sends Bob 2 bitcoin
(INVALID transaction)



Double-Spend Attack

Alice has 2 bitcoin
Alice sends 1.5 bitcoin to Bob
Alice sends 1.5 bitcoin to Charlie



Two “Levels” of a Bitcoin Transaction

- Transaction pool (“mempool”) - A transaction that has been found to be valid based on previous information (but may be part of a double-spend or have other issues)
  - These are subject to being dropped, although it is unlikely
- Blockchain - A transaction that has been “mined” and now considered part of the immutable history of the Bitcoin network
  - Also liable to be dropped, but MUCH less likely
  - After an hour or two, ASTRONOMICALLY unlikely

Mining

- There are certain computers on the network which act as "miners"
- Miners bundle up transactions into blocks
- They are rewarded every time they create a block (thus, "mining") with a "block reward" and the transaction fees in all of the transactions

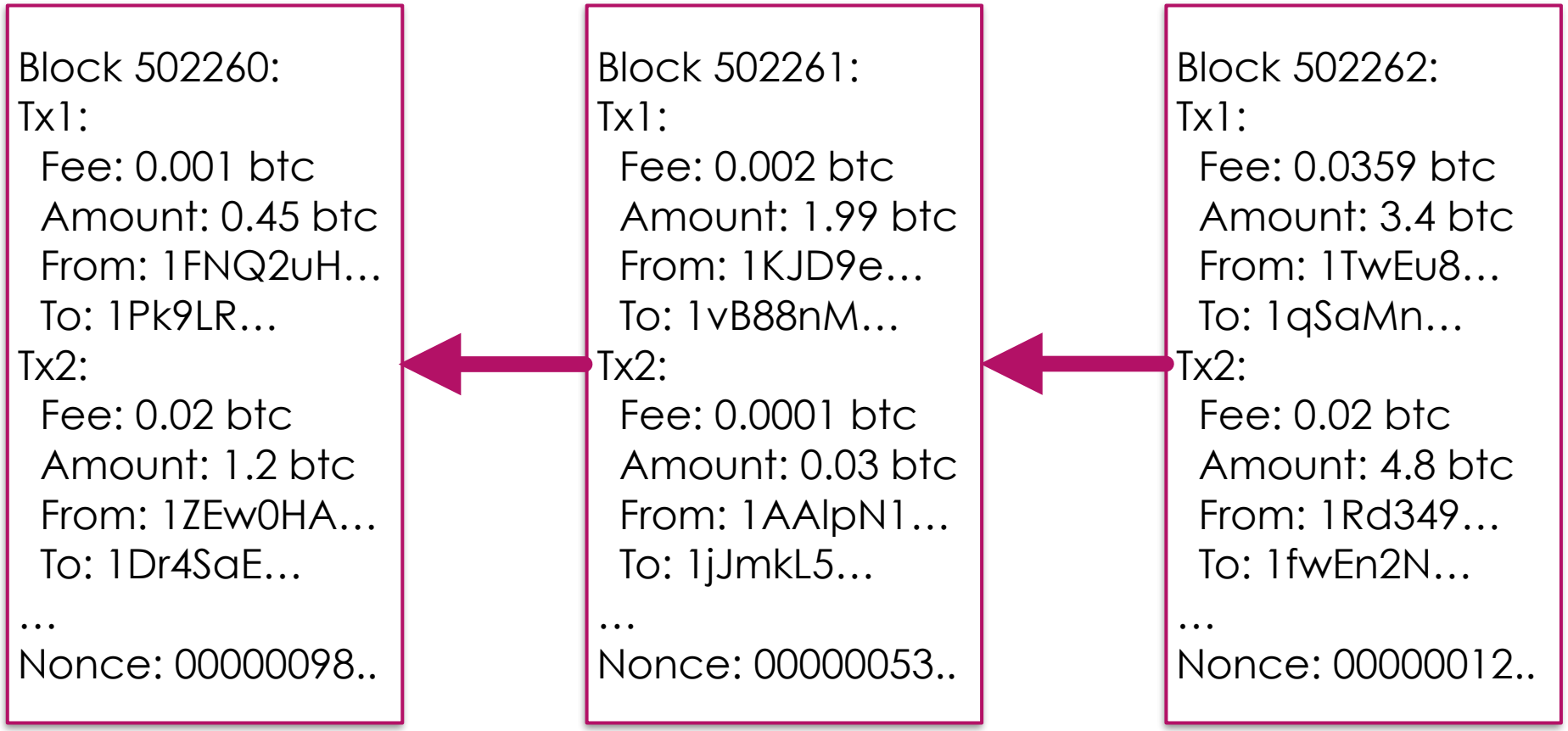
The Blockchain

- The blockchain is the "ground truth"
  - Miners bundle up valid transactions into "blocks"
  - They do lots of difficult calculations to make it a valid block (this is called *proof-of-work* - it proves that the miners are spending time and energy on securing the network)
  - First miner to figure out the solution and make a block, broadcasts it out to all nodes and other nodes check - hard to calculate but easy to verify
  - That miner gets all transaction fees (~ 0.01 - 0.3 bitcoin recently, has been as high as ~ 13 bitcoin) in the block plus a "block reward" (currently 12.5 bitcoin)
  - The block reward is where all bitcoin originate

The Blockchain

- Adding a block to the blockchain takes massive amounts of computing power
  - Specialized computers - ASICs - are used for this purpose - ordinary computers are orders of magnitude too slow
  - Current Bitcoin network “hashrate”: 36 quintillion hashes per second
  - Takes ~ 10 minutes to make a block
  - Note that ~ 10 minutes is self-correcting

The Blockchain



The Blockchain

- **For small transactions:** seeing the transaction is valid in the mempool is probably enough security (double-spends are difficult to do correctly)
- **For medium-sized transactions:** wait until it has been confirmed and in a block
- **For large-scale transactions:** wait until confirmed by six blocks

Decentralized, Trustless, Deflationary

- If you are running a full node, there is never a need to trust any other nodes
- It is easy for your computer to verify that everybody is following the rules
- This means that there is no central authority on the network
- Inherently deflationary - only 21 million bitcoin will ever be mined
- If you lose your key or send to a bad address - those bitcoin are gone!

Strengths

- Trusted, transparent transactions
- Censorship resistance (easy to bypass regulatory controls)
- Fast long-distance and cross-border transactions
- In-system inflation is set by the algorithm

Weaknesses

- Very unforgiving
- Censorship resistance (easy to bypass regulatory controls)
- Volatile pricing
- Possible weaknesses in algorithm or code
- Inflation cannot be controlled by external sources

Other Popular Cryptocurrencies

- Ethereum
- Ripple
- Dogecoin
- Monero
- Vertcoin

Questions?

PDF of slides available at:
https://github.com/laboon/fei_bitcoin

BILL LABOON (LABOON@CS.PITT.EDU)

LECTURER, COMPUTER SCIENCE DEPARTMENT, UNIVERSITY OF PITTSBURGH