



CS1699: Blockchain Technology and Cryptocurrency

10. Using Bitcoin

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Using Bitcoin

- ❖ *Owning bitcoin* really means:
 - ❖ “I have the ability to control any UTXOs sent to some set of addresses (loosely, public keys) and generate new transactions from them...
 - ❖ ... which I can prove by signing said transactions with the corresponding secret keys for each address.”

Public Keys \neq Addresses

- ❖ Although a public key can be a kind of public address (as in StringCoin), in Bitcoin it is slightly more complex
- ❖ Your address is $A(pk)$, where $A()$ is a rather convoluted multi-hashing process (see next slide)
- ❖ Thus, P2PKH (“pay-to-public-key-hash”) as opposed to P2PK (“pay-to-public-key”)
- ❖ Addresses are generally represented in *Base58Check* format

Base58Check Encoding

- ❖ Just like binary (base 2) has 2 possible values (01), octal (base 8) has 8 (01234567), hexadecimal (base 16) has 16 (0123456789ABCDEF), Base58 has 58 (123456789ABCDEFGHJKLMNPQRSTUVWXYZabcdefghijklmnopqrstuvwxyzvwxyz)
- ❖ Note that O (capital O), 0 (zero) , l (lowercase L), and I (capital i) are omitted to avoid confusion
 - ❖ Thus, the “1” at the beginning of standard Bitcoin addresses actually means the value “0”!
- ❖ Base58Check also includes a four-byte checksum at the end to ensure accurate transcription

A Number Base58Check is still a NUMBER

- ❖ Can represent as a QR code (2-d barcode)



- ❖ Or decimal:
5579715324429201893029744493272740905093118947118065324001,
- ❖ Or binary:
1110001110001110111100100011011000100100100010010100000000011111111010100000000
0011100111011001011101111010101110110001110011100110110111101010110001011101000
1100000110010010110000111111100001

Bitcoin Address Generation From a Public Key

1. Generate an ECDSA keypair, and take its public key
2. Take the SHA-256 hash of the public key.
3. Take the RIPEMD-160 hash of the SHA-256 hash generated in the step above.
4. Prepend a “0” (i.e. “1” :)) to indicate this is a Bitcoin Mainnet address.
5. *Take the SHA-256 hash of the prepended RIPEMD-160 hash.*
6. *Take the SHA-256 hash of the previous SHA-256 hash.*
7. *Take the first four bytes of that last SHA-256 hash and store it as a checksum.*
8. Append the four-byte checksum to the end of the prepended address found in Step 4.
9. Convert the result from Step 8 to Base58Check encoding (see next slide).

Steps in italics represent checksum calculations.

What If I Want A Specific Address?

- ❖ 1CS1699xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx is a valid address, I want it!
- ❖ Recall that generating an address means taking a randomly generated public key, prepending it with 1, then hashing it (twice, with two different hash algorithms) then adding a checksum
- ❖ Ergo, generating an address equal to a value or matching some pattern can be seen as a kind of Bernoulli trial

Vanity Address Generation

- ❖ Just like mining, we can just keep trying with different inputs
- ❖ For each character we want, there is a $1/58$ chance we will get the correct one, ergo chances are $1/58^k$ for a k -character pattern
- ❖ Luckily, programs can do this for us... do this locally! Keys have been stolen from “online vanity generators!”
- ❖ Also note that there are some possible efficiency optimizations over sheer random guesses, see book for details
- ❖ <https://github.com/samr7/vanitygen>

Vanity Address Generation

```
$ time ./vanitygen 1C
Address: 1CXakjLjyXCb54nY78C9dzZtTbuLsSv2sT
Privkey: 5Kk7QVaupb8YDLHDJmrfCnZ582kPsCCQLWKZFXGuxVbY61cXwz
real 0m0.016s
```

```
$ time ./vanitygen 1CS
Address: 1CSsTLkrKDziit54WDemuagM5jbqALhims
Privkey: 5KLvhtRKHkRLP2rf5dMoTBrWmJRVOM78p773cbr6of3ZsHR8Ljp
real 0m0.016s
```

```
$ time ./vanitygen 1CS1
Address: 1CS1Koo5r9jqMBsMaNjazVpSzXuUvdqdG7
Privkey: 5JMP4B5LrkeKe2WaJpPt1xn7vqRg1r1WBKt9TxHSK2KkLc2Jubc
real 0m0.526s
```

```
$ time ./vanitygen 1CS16
Address: 1CS16y6VQSTzoK8eGGeBwQGW9rCTgecV28
Privkey: 5KFeGex4kwq1hJ5psh3fBW5Yn3kbSqsi4aRq3iehBoy9G97S8qk
real 0m23.411s
```

```
$ time ./vanitygen 1CS169
Address: 1CS169cXfqKyTfJR1jLY6mGwQMBtWDfbx8
Privkey: 5KLyxp1qZvpTjV9mZsQF4117wPcuFUx3UGcY7xn7aTEUwtYcZLj
real 10m40.580s
```

How Do I Store My Bitcoin?

- ❖ Storing bitcoin is ALL about managing your secret (and to a lesser extent, your public) keys
- ❖ But there are a variety of ways to do so, with various trade-offs, mainly:
 - ❖ Availability
 - ❖ Security
 - ❖ Convenience

Hot vs. Cold Storage

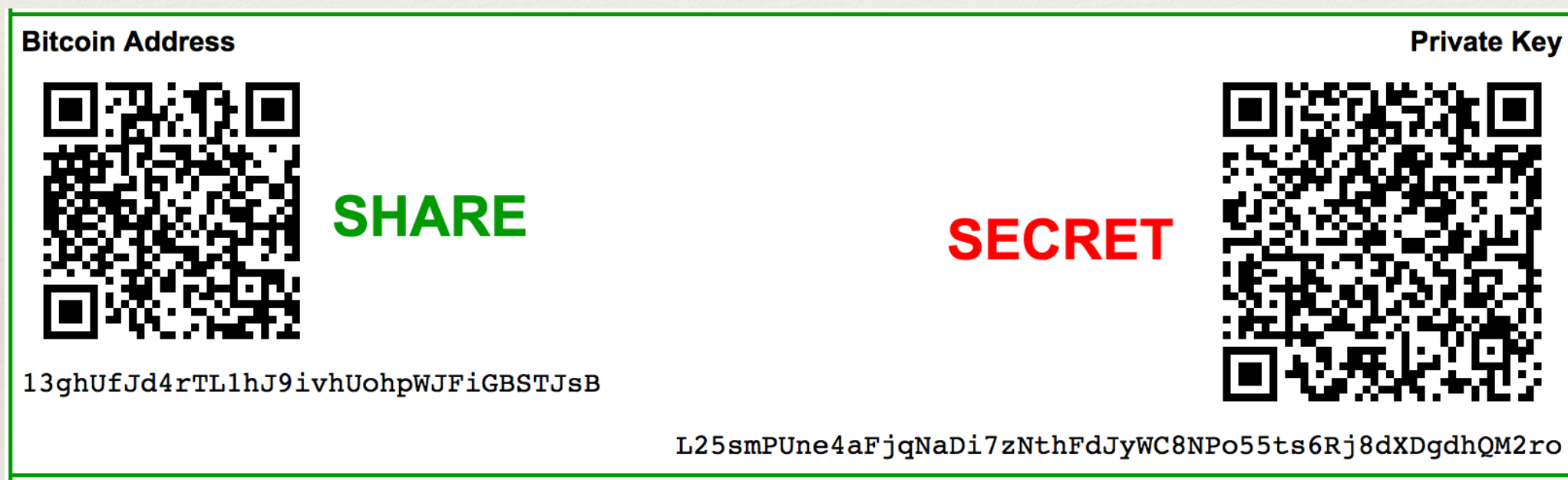
- ❖ **Hot storage:** Bitcoin can directly be spent on the Bitcoin network (i.e. node or node-proxy is online)
- ❖ **Cold storage:** Bitcoin cannot directly be spent on the Bitcoin network (i.e. secret keys are offline)
- ❖ **Note:** Cold storage retains the possibility of sending Bitcoin to it even if offline, however, as long as a valid public key is known

Wallet Software (Hot)

- ❖ Software on your computer or phone which keeps track of your keys, coins, makes transactions, etc.
- ❖ Usually a SPV node or connected to a SPV node
- ❖ Think of it as the wallet in your pocket - simple to use and understand, but pickpockets are rife!
- ❖ Availability: **HIGH**, Convenience: **HIGH**, Security: **LOW**

Paper Wallet (Cold)

- ❖ A generated address / secret key which is printed out and kept on piece of paper



- ❖ Availability: **LOW**, Convenience: **MEDIUM**, Security: **MEDIUM/HIGH**

Brain Wallet (Cold)

- ❖ Remember a pass phrase and use the hash of it as a seed to pseudorandomly generate a keypair

Enter Passphrase:

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Show? ☒

Print

Compressed address? ☐ [View](#)

Algorithm: SHA256(passphrase)

Warning: Choosing a strong passphrase is important to avoid brute force attempts to guess your passphrase and steal your bitcoins.

Bitcoin Address:
149xTKLM6guqBREhXrqJmBajCFNre5ANEy

Private Key (Wallet Import Format):
5J1LmFc8PuDt2SMqKc9gZeZBNGAzPtg2shjfhUT2FuK2X7iBzDq

- ❖ Availability: **LOW**, Convenience: **LOW**, Security: **HIGH**

Hardware Wallet (hybrid hot/cold)

- ❖ Simple devices (not full computers) which generate keys but secret keys never leave device
- ❖ Transactions are fed in, signed, and output
- ❖ Examples: Trezor or Nano
- ❖ Availability: MEDIUM, Convenience: MEDIUM, Security: HIGH

Why Address Re-Use Is A Bad Idea

- ❖ Leaks information about your identity
- ❖ Assume you have been sending transactions all of your life to a single address. If anyone links that address to you, they know you have several hundred thousand dollars in Bitcoin.
- ❖ Assume you pay your landlord in Bitcoin from the same address every month and get paid from your employer to the same address. Now your landlord knows you can afford a raise in rent.
- ❖ A Bitcoin wallet can generate a large (in practical terms, infinite) number of addresses, so let's use them

Hierarchical Deterministic Wallets

- ❖ Instead of a wallet specifically generating an address, it generates a way to create a series of unlinked addresses, but to which it has all of the secret keys
- ❖ Now you can have as many addresses as you like, but “see” them all in your wallet as a single Bitcoin “address”
 - ❖ Recall that tx inputs can come from multiple addresses!
- ❖ See BIP 32 <https://github.com/bitcoin/bips/blob/master/bip-0032.mediawiki>

Splitting and Sharing Keys

- ❖ Assume my wife and I want veto power over spending from our joint Bitcoin account - i.e., we both need to agree that Bill buying a Bitcoin sweater is a good use of our funds, and so we want to only be able to reconstruct our key if both of us agree
- ❖ How can I do this?

Naive Splitting

- ❖ Public address is: 149xTKLM6guqBREhXrqJmBajCFNre5ANEy
- ❖ Secret key is:
5J1LmFc8PuDt2SMqKc9gZeZBN**GAzPtg2shjfhUT2FuK2X7iBzDq**
- ❖ I know the red part of the secret key, she knows the blue part - we have to put them together in order to actually sign anything (and thus spend our bitcoin)
- ❖ Several problems with this scenario!

Secret Sharing - K of N

- ❖ Idea: Given some values K and N and $K \leq N$, can we split the key into N pieces such that if we have K shares, we can determine the key...
- ❖ ... but having any number of shares n (where $n > 0$ and $n < K$), we will not gain any knowledge of the key?

Secret Sharing

- ❖ Suppose $N = 2$, $K = 2$, and our secret key S is 128 bits.
- ❖ Generate a random 128-bit value R .
- ❖ Two shares: R and $(S \text{ XOR } R)$
- ❖ Together, can calculate S ; otherwise, basically random numbers
- ❖ Can extrapolate out to any $N \geq 2$ and $K \geq 2$ BUT N must equal K .

What If We Want $K \neq N$?

- ❖ Example: I want to bequeath my bitcoin to my son upon my death. I want to split my key into three, so that 2/3 of my lawyer, me, and my wife can determine my key.
- ❖ Or extrapolate this out further: 2 out of 6 board members must agree to spend money from a corporation's bitcoin account, or 5 out of 9 justices on a court must agree to pay bitcoin held in escrow

2-of-n Secret Sharing

Secret key = 5

Share₁ = 3, 8

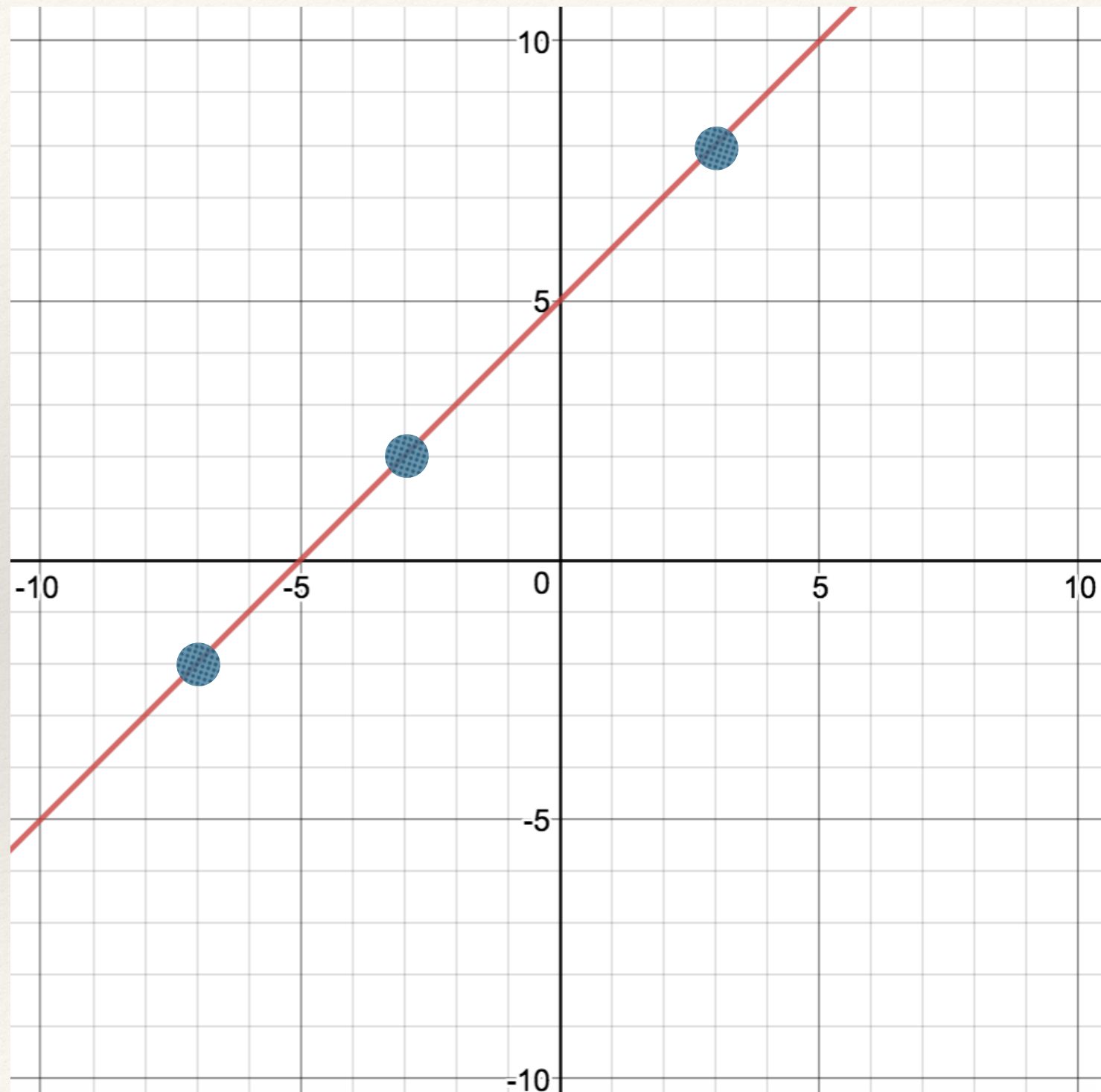
Share₂ = -3, 2

Share₃ = -7, -2

Share_n = ...

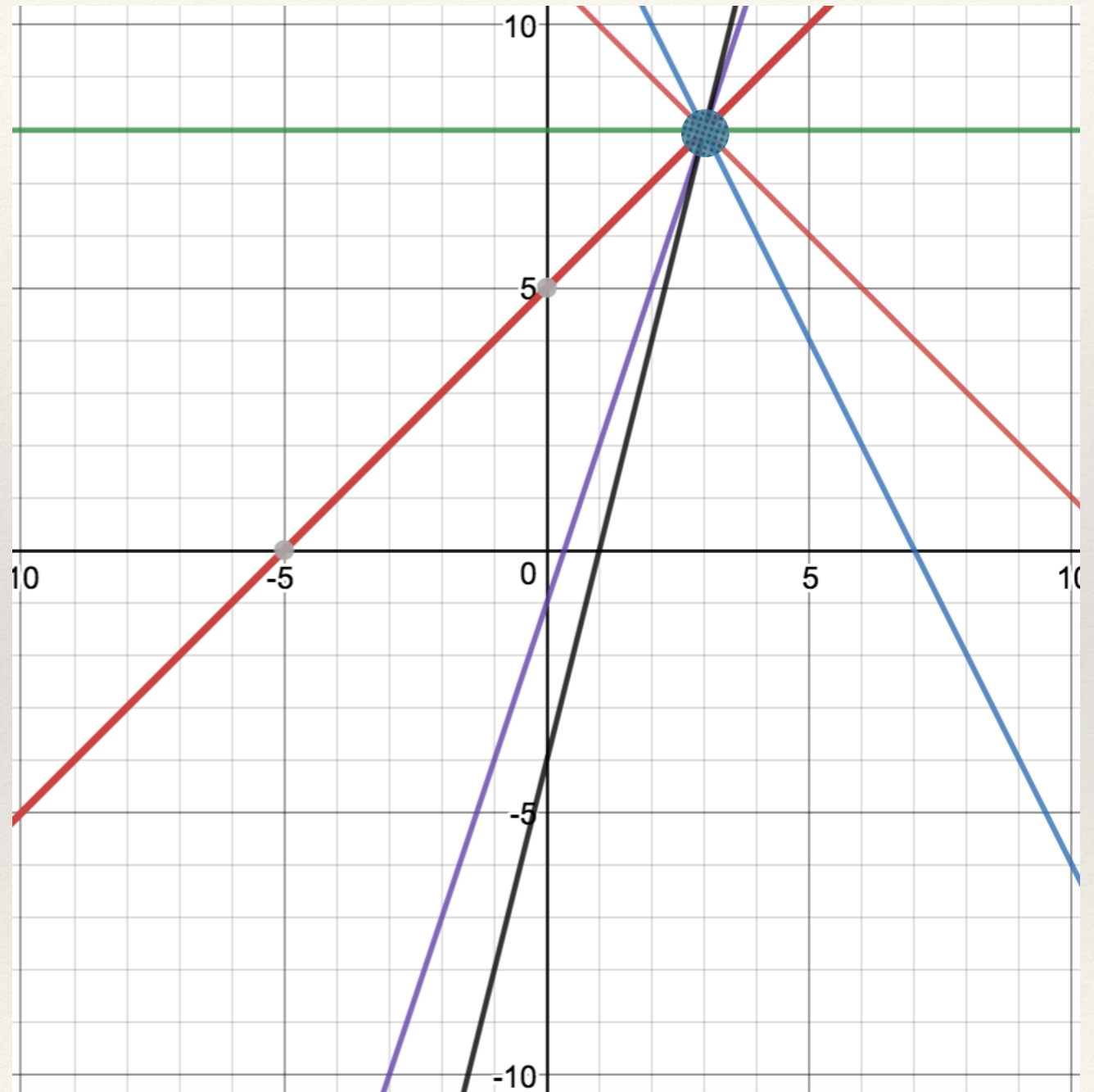
Slope: $y = x + 5$

*Can calculate slope -
and thus intercept -
iff I have 2 or more
points on the line*



2-of-n Secret Sharing, One Share

*With one share (point) - e.g. 3, 8 -
I cannot determine the slope...
thus cannot determine the intercept...
thus cannot determine the key.*



3-of-n Secret Sharing

Secret key = 4

Share₁ = -4, 20

Share₂ = 1, 5

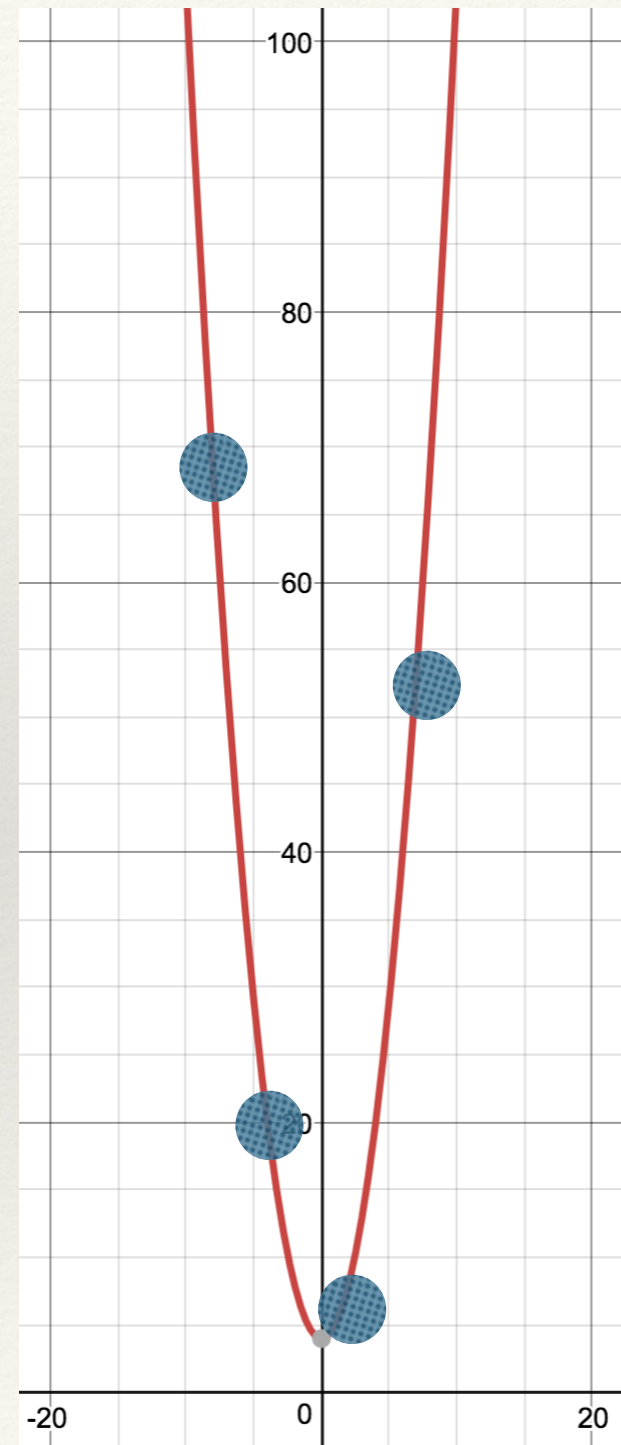
Share₃ = 7, 53

Share₄ = -8, 68

Share_n = ...

Source Function: $y = x^2 + 5$

*Can recreate function -
and thus determine intercept -
iff I have 3 or more
points on the parabola.*



Arbitrary k -of- n Secret Sharing

- ❖ Determine *key* (randomly)
- ❖ Determine k , and randomly generate a $(k-1)$ —order polynomial which intersects origin at 0 , *key*
- ❖ Determine n random points on the function and distribute
- ❖ Can expand indefinitely via Lagrange interpolation

Threshold Signatures

- ❖ Problem with previous schemes - they all generate the actual secret key, which is a point of weakness (key can be stolen after reconstruction and used on its own)
- ❖ There is a (mathematically complex) way to make partial signatures and if enough actors generate partial signatures, they can sign a transaction with a key without ever revealing the key or even their key shares
- ❖ Avoids the single point of failure problem above

Online Wallet

- ❖ Software runs online where you have an account
- ❖ You will either need to enter key or they will store it in an encrypted format
- ❖ Very convenient! No installation on your part.
- ❖ If you don't have the keys, though, or they are grabbing keys that you pass in, big security worry. NOT YOUR KEYS, NOT YOUR COINS!
- ❖ <https://login.blockchain.com/#/signup>

Online Exchange

- ❖ Online wallet plus place to buy / sell bitcoin (like a stock exchange... I'll give you \$9.25 for one share of Ford, or I'll give you \$6,595.76 for one bitcoin)
- ❖ *Fractional reserve* - Just like real banks, exchanges promise to give you your bitcoin when you ask for it, but may not actually have it!
- ❖ Very convenient, offloads responsibility, but there are risks with trusting any bank

Risk 1: Bank/Exchange Runs

- ❖ Many people ask for their money back at a bank; bank does not have enough cash on hand
- ❖ Rumors spread that bank is insolvent
- ❖ More people try to cash out, exacerbating problem
- ❖ In US, bank accounts are backed by FDIC so this *shouldn't* happen (since the FDIC can always print more money... can't print more bitcoins!)

Risk 2: Counterparty Risk

- ❖ Bank / exchange is not really planning on giving people the bitcoin that is rightfully theirs
- ❖ “Exit scam”
- ❖ Ponzi scheme: paying people who ask for bitcoin with newcomer’s bitcoin

Risk 3: Security Breach

- ❖ A hacker could break into the exchange's software and move all of their bitcoin
- ❖ There is no “arbiter” to determine who “rightly” owns some bitcoin
- ❖ “Why do you rob banks? ‘Cause that’s where the money is.” -supposedly said by Willie Sutton

Some Possible Systemic Bitcoin Risks

- ❖ Sybil attack via peers (i.e., flood network with “bad” peers, new connections may see only bad peers)
- ❖ Adding illegal content to blockchain (regulatory risk)
- ❖ Major weakness in SHA-256, RIPEMD-160, ECDSA, or other cryptographic algorithm
- ❖ Quantum attacks - quantum computers can factor large numbers very quickly
- ❖ Security vulnerabilities / defects
- ❖ Timejacking
- ❖ Denial of service attacks
- ❖ Mining death spiral - no longer profitable to mine, so fewer miners, so less interest in bitcoin, so lower price, so even less profitable to mine, *ad infinitum*