Bitcoin and Blockchain

Overview

- Bitcoin address
- Bitcoin transactions
- Locking and unlocking script
- Blocks and Bitcoin mining
- Blockchain

Bitcoin Address

Elliptic Curve Cryptography

$$y^2 = x^3 + 7$$

Generating Public and Private Keys

```
Private-Key: (256 bit)
priv:
    01:68:d2:65:bf:f8:66:88:e0:b0:64:d5:76:cc:7d:
    51:ae:1d:5b:62:64:fd:2e:1e:24:ec:53:eb:5d:9d:
    0c:20
pub:
    04:73:e3:c6:ce:48:da:81:fd:c1:04:86:74:83:4f:
    06:27:85:88:c4:af:59:7b:bf:bc:a6:ef:5a:57:52:
    07:16:bc:b7:15:f8:a4:f5:16:f0:a7:20:2a:1a:59:
    e4:8b:0d:41:f7:ab:ae:ba:86:3c:37:4a:79:7c:02:
    75:3b:34:27:d7
ASN1 OID: secp256k1
```

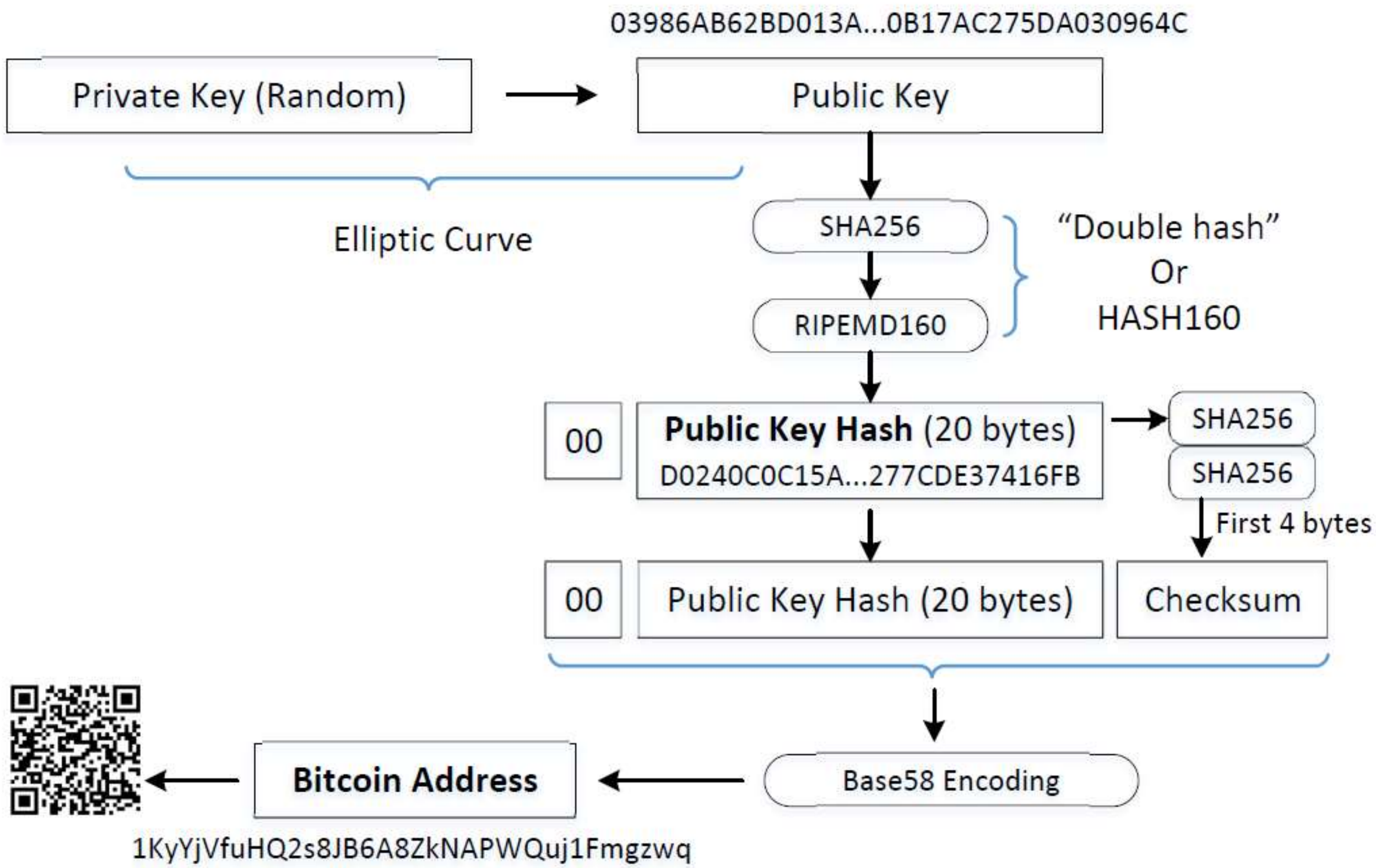
Compressing Public Key

```
pub:
    03:73:e3:c6:ce:48:da:81:fd:c1:04:86:74:83:4f:
    06:27:85:88:c4:af:59:7b:bf:bc:a6:ef:5a:57:52:
    07:16:bc
ASN1 OID: secp256k1
```

Generating Public-Key Hash

```
$ echo 0373e3c6c...5a57520716bc | xxd -r -p \
        | openssl dgst -sha256 -binary      \
        | openssl dgst -ripemd160
(stdin)= 9390b28a0280cde7eac94e410a74f652aed6e937
```

Turning Public-Key Hash into Bitcoin Address



Base58 Encoding

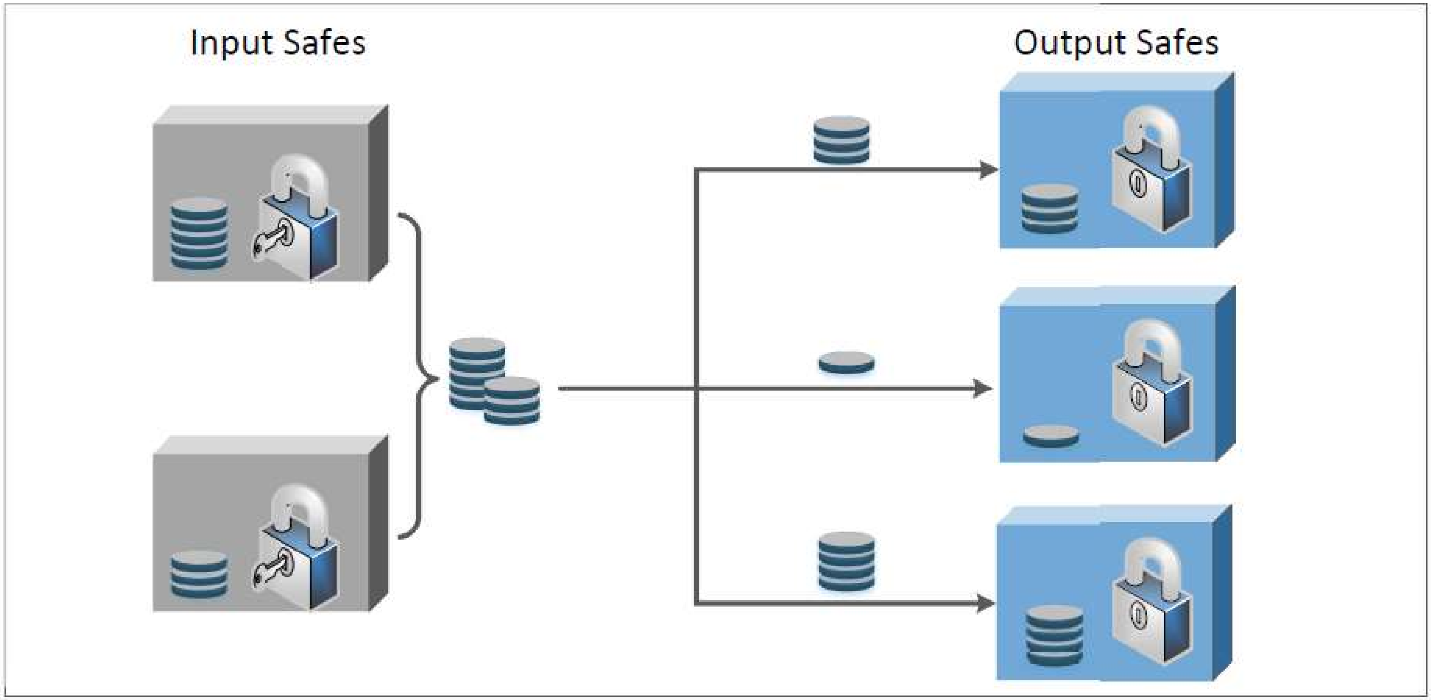
Integer	Division	Quotient	Remainder	Base58 Symbol
2,864,386,338	div 58	49,385,971	20	M
49,385,971	div 58	851,482	15	G
851,482	div 58	14,680	42	j
14,680	div 58	253	6	7
253	div 58	4	21	N
4	div 58	0	4	5

Final Base58 encoding: **5N7jGM**

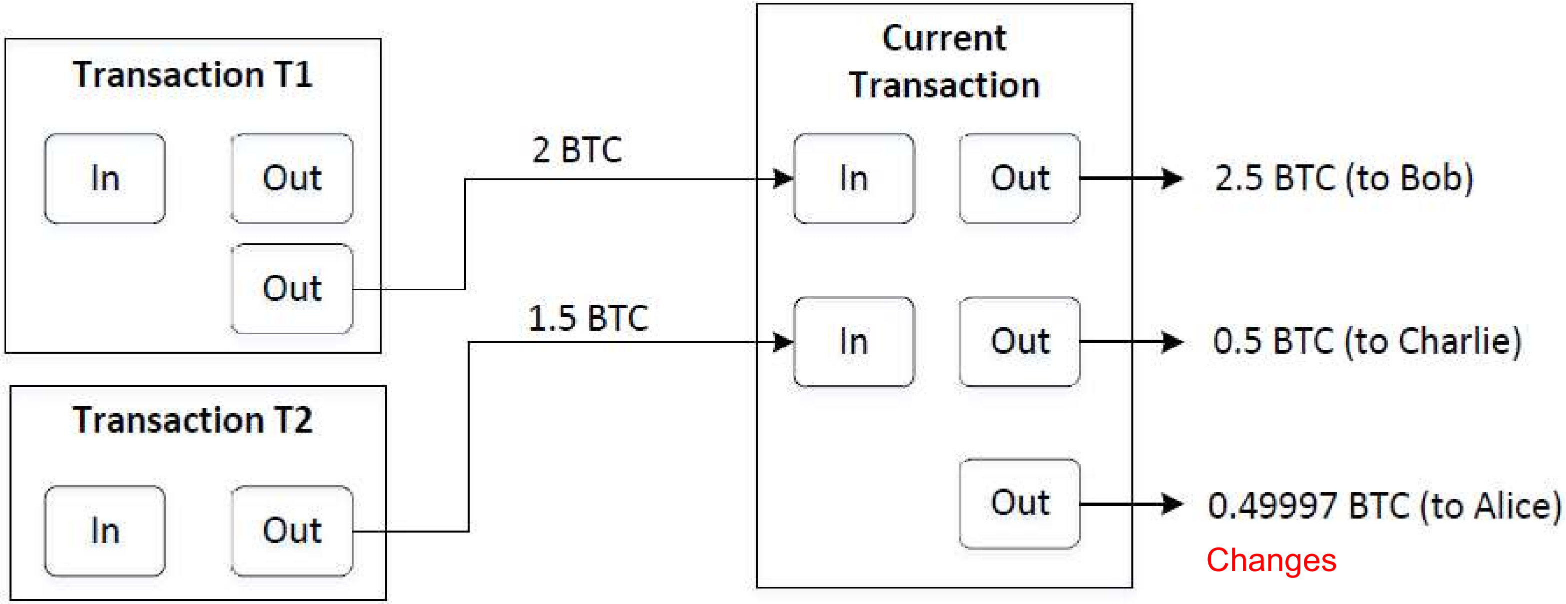
```
$ echo aabb1122 | xxd -r -p | python base58.py && echo
5N7jGM
$ echo 009390b28a0280cde7eac94e410a74f652aed6e937b2b07b3f \
    | xxd -r -p | python base58.py && echo
1ETFfxDNaF8rWsuorMKhdHruxSuT9BDUGE
```

Transactions: Intuition

Components of Transactions & Examples

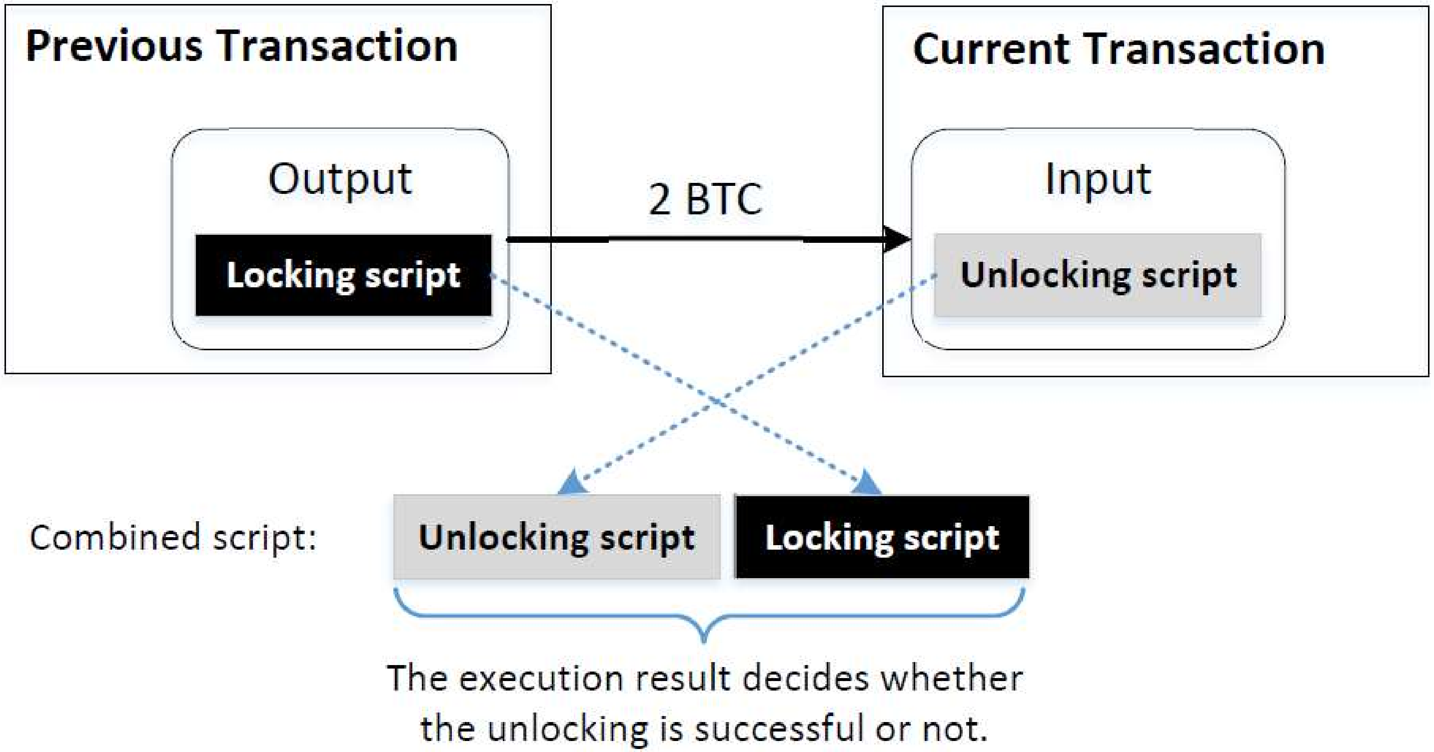


An Example



Transaction fee = (2 + 1.5) – (2.5 + 0.5 + 0.49997) = 0.00003 BTC

Locking and Unlocking Script



Script Examples

```
scriptPubKey: OP_RETURN
scriptSig: ... (does not matter)

Combined script: ... (does not matter) ... OP_RETURN
```

```
scriptPubKey: OP_ADD <100> OP_EQUAL
scriptSig:    <5> <95>

Combined script: <5> <95> OP_ADD <100> OP_EQUAL
```

```
scriptPubKey: OP_SHA256 <6fe2...3ffe> OP_EQUAL
scriptSig:    <f343...f0f5>

Combined script:
    <f343...f0f5> OP_SHA256 <6fe2...3ffe> OP_EQUAL
```

Pay-to-PubKey-Hash (P2PH)

```
scriptPubKey: OP_DUP OP_HASH160 <Public KeyHash> OP_EQUAL OP_CHECKSIG
scriptSig:    <Signature> <Public Key>

Combined script: <Signature> <Public Key> OP_DUP OP_HASH160
                 <Public KeyHash> OP_EQUAL OP_CHECKSIG
```

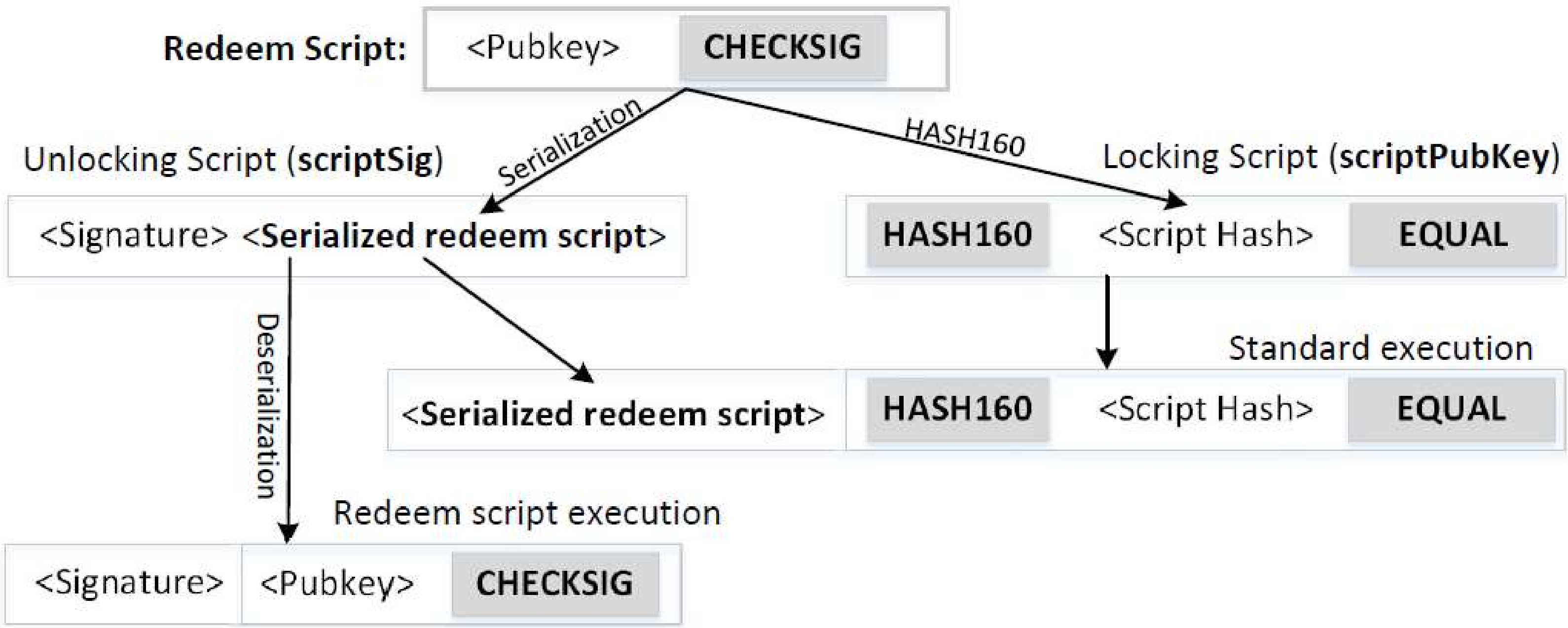
Pay-to-MultiSig (P2MS)

```
scriptPubKey: <2> <PubKey 1> <PubKey 2> <PubKey 3> <3>
              OP_CHECKMULTISIG
scriptSig: <Signature 1> <Signature 2>

Combined script:
    <Signature 1> <Signature 2>
    <2> <PubKey 1> <PubKey 2> <PubKey 3> <3> OP_CHECKMULTISIG
```

Pay-to-Script-Hash (P2SH)

```
scriptPubKey: OP_HASH160 <Script Hash> OP_EQUAL
```

```
scriptSig: <Unlocking Script> <Serialized Redeem Script>
```



Use P2SH for MultiSig

Pay-to-MultiSig (P2MS)

```
scriptPubKey: <2> <PubKey 1> <PubKey 2> <PubKey 3> <3>
              OP_CHECKMULTISIG
scriptSig: <Signature 1> <Signature 2>

Combined script:
    <Signature 1> <Signature 2>
    <2> <PubKey 1> <PubKey 2> <PubKey 3> <3> OP_CHECKMULTISIG
```

Pay-to-Script-Hash (P2SH)

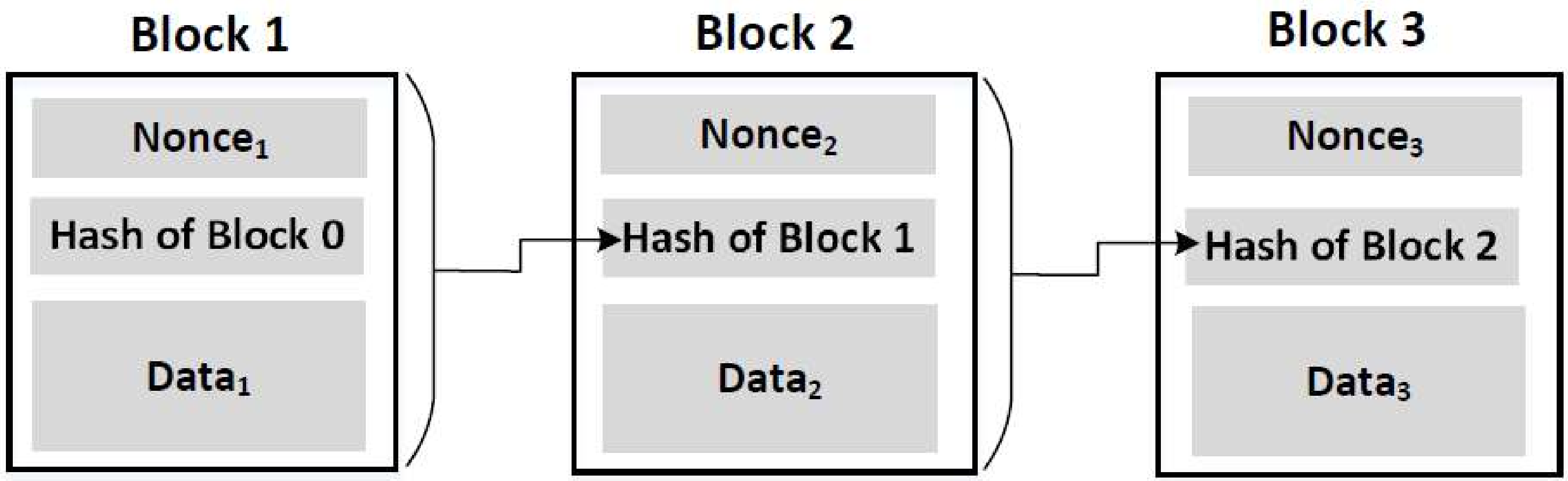
```
Redeem Script:
   <2> <PubKey 1> <PubKey 2> <PubKey 3> <3> OP_CHECKMULTISIG

scriptPubKey: OP_HASH160 <Hash of Redeem Script> OP_EQUAL
scriptSig:    <Sig 1> <Sig 2> <Serialized Redeem Script>
```

Sending Transaction

- After a node has generated a transaction, it sends the transaction to its peers
- Each peer will verify the transaction, and then forward it to their peers
- Eventually, every node on the network will receive the transaction
- Some special node called miner will be responsible for adding the transaction to the public ledger (i.e., blockchain).

Generating Blocks

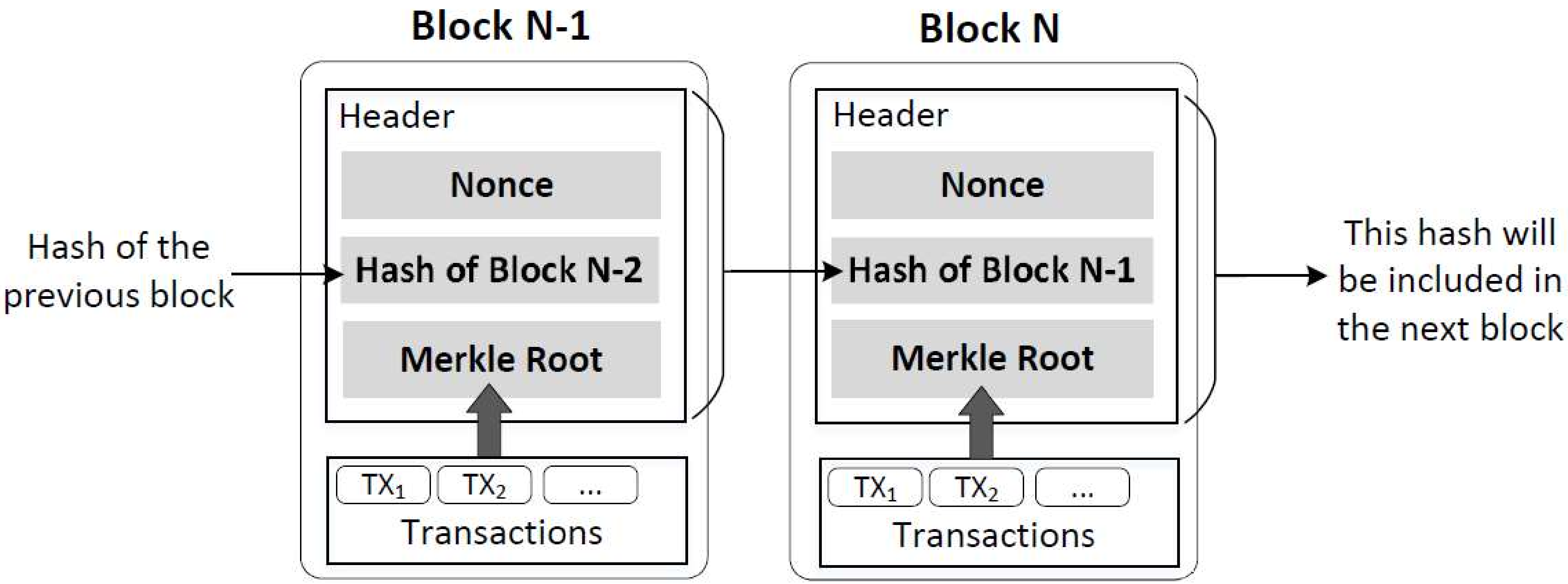
- Miners group transactions into a new block
- The new block is appended to the existing blockchain



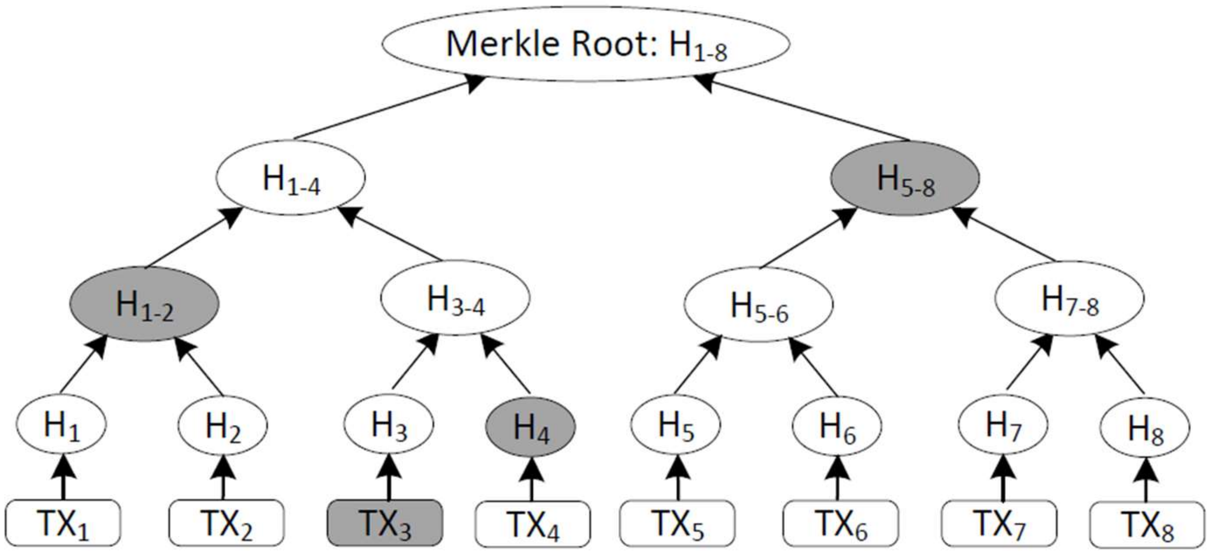
Mining

- Proof-of-Work: find a nonce, s.t. when the hash of the block satisfies a special requirement, such as having 20 leading zeros
- Rewarding:
  - Coinbase transaction: new bitcoins are minted and given to the miner
  - Transaction fees
- Once a miner has found a block, it immediately sends the block to its peers, who will verify the block and then forward the block to their peers.
- Eventually, all the nodes will see this new block, and add it to their ledgers.

Include Merkle Root in Block



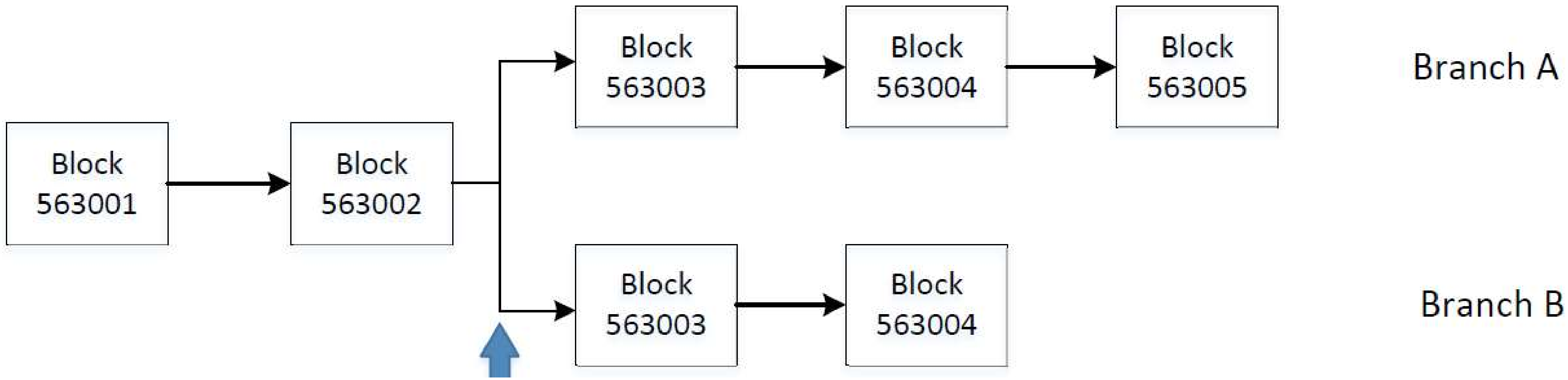
Merkle Tree



Benefit:

- To find whether a transaction is included in a block, you don't need all the transactions
- Good for non-full nodes

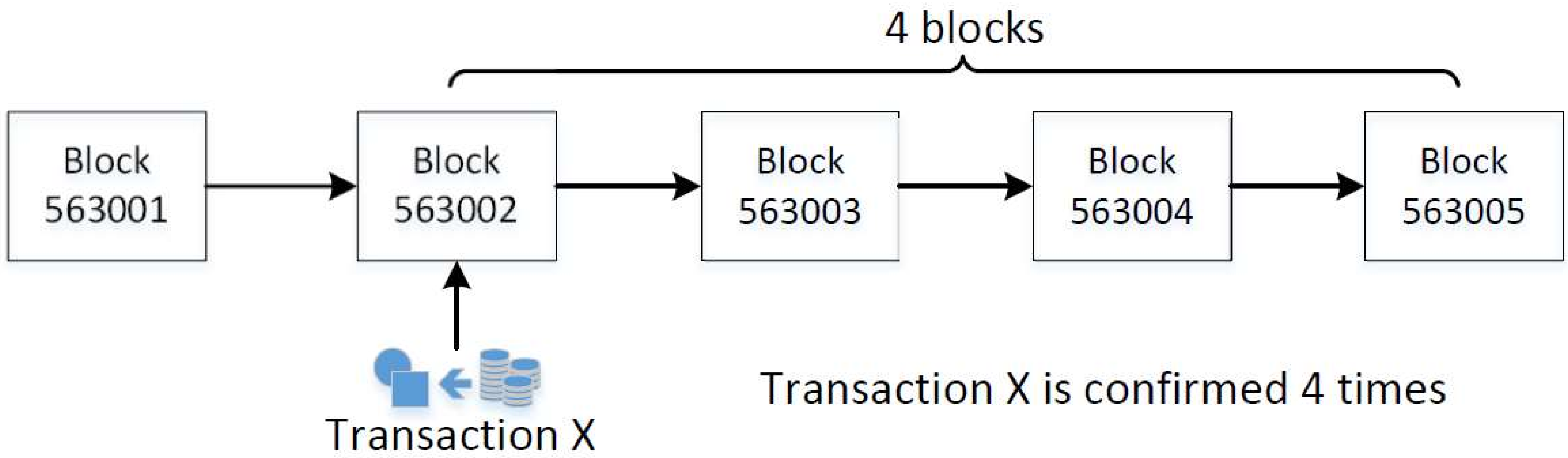
Branching



Branching occurs when two valid blocks are found at about the same time

The longest chain wins

Confirmation Number

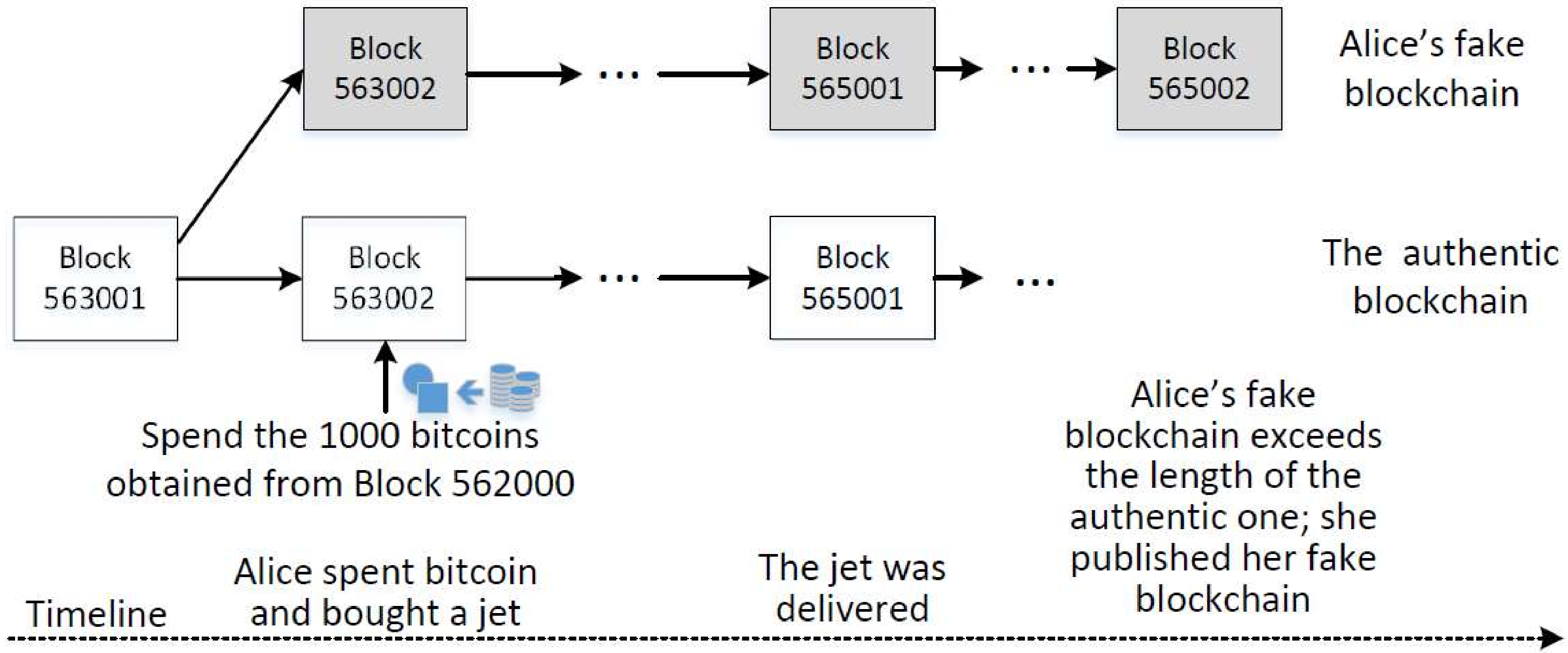


The larger a block’s confirmation number is, the less likely it will be removed from the blockchain

Probability of Double Spending

Confirmation	2%	8%	10%	20%	30%	40%	50%
1	4%	16%	20%	40%	60%	80%	100%
2	0.237%	3.635%	5.600%	20.800%	43.200%	70.400%	100%
3	0.016%	0.905%	1.712%	11.584%	32.616%	63.488%	100%
4	0.001%	0.235%	0.546%	6.669%	25.207%	57.958%	100%
5	≈ 0	0.063%	0.178%	3.916%	19.762%	53.314%	100%
6	≈ 0	0.017%	0.059%	2.331%	15.645%	49.300%	100%
7	≈ 0	0.005%	0.020%	1.401%	12.475%	45.769%	100%
8	≈ 0	0.001%	0.007%	0.848%	10.003%	42.621%	100%

Double Spending with Majority Hash Power



Summary

- Bitcoin address
- Transactions, locking and unlocking script
- Bitcoin mining
- Blockchain, branching, confirmation number, and double spending