Evaluating the Feasibility of Proposed Blockchain Use Cases

Blockchain Technology: An Emerging Issues Forum

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Bitcoin: a true breakthrough

- Satoshi Nakamoto's brilliance was his extremely clever combination of existing technologies to tightly meet the needs of a cryptocurrency.

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The tremendous interest in blockchain

- Many other sessions at this conference will cover this.
- A November 2017 report from Deloitte captures both the interest and the controversy.
  - GitHub is an open-source software development platform.
  - 86,034 blockchain projects
    - Only about 9,400 from organizations rather than individuals
    - 26,885 in 2016 alone
    - 92% have been abandoned.

What uses are being suggested at this conference?

- REA smart contracts
- Shared ledger system for financial accounting
- Automobile registration
- Food supply tracking

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Comparing proposed uses with Bitcoin

- Bitcoin is the "proof of concept" for blockchain.
- Many proposed uses have characteristics that differ greatly from Bitcoin.
- The requirements for those uses probably differ greatly from Bitcoin's requirements.

A fundamental question

- Can a technological solution designed to closely meet a cryptocurrency's needs work well with applications that are very different?

Does Bitcoin really work?

- "Bitcoin works in practice but not in theory."
- In 2015, Bonneau and others claimed: "We do not yet have sufficient understanding to conclude with confidence that Bitcoin will continue to work well in practice . . ."

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Does Bitcoin really work?

- This remains an open question in the computer science literature.
- Perhaps Bitcoin works only because its participants believe it works, regardless of any underlying fatal flaw!

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A suggested approach

- Identify the requirements of a specific application.
- Explain how the proposed technological solution meets those requirements.
- This has been accepted IT practice for decades.

Matching the solution to the requirements

- We must deeply understand how the technologies used in blockchain work.
  - A superficial understanding can lead to incorrect conclusions.

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What we will cover

- Bitcoin's requirements
- An overview of the technologies in blockchain
  - There's likely a very wide range of understanding among the conference participants.
- Blockchain structure and data retrieval
  - A stumbling block (*pardon the pun*) for many proposed uses.
- What about SegWit, Ethereum, and Hyperledger Fabric?

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The cypherpunks

- Started in 1992 by Eric Hughes, Tim May, and John Gilmore.
  - Hughes wrote “A Cypherpunk’s Manifesto” in 1993.
- Led to monthly meetings at Gilmore’s company, Cygnus Solutions.
- Created mailing list with hundreds of subscribers.
  - Use of then-novel encryption methods ensured complete privacy. Ideas were shared freely.
  - Personal privacy and personal liberty were paramount.
- Based on principles in the manifesto, several proposals were made for digital cash.

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The cypherpunks

- Bitcoin is part of the cypherpunk "heritage."
  - Strong resistance to government or any other central authority
- A digital currency *could* be issued by a central authority.
- Much of the technological foundation of blockchain exists specifically to avoid having a central authority in Bitcoin.
- Many proposed uses of blockchain involve government or some other central authority.
  - Does this give you pause?

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Requirements for Bitcoin

- Scarcity to provide value
- No central authority
  - Cypherpunk legacy
- No need to trust individual participants
- Privacy through anonymity
- Prevent double-spending.
- Units must be divisible.

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How blockchain meets these requirements

- Peer-to-peer network
- Public/private key encryption
- Fully consuming the original bitcoin and providing "change"
- Hashing
- Linked blocks of transactions
- Merkle tree
- Proof of work
- Game theory and group consensus

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How does blockchain meet these requirements?

- This is an extraordinarily complex topic.
- In an attempt to simplify, many explanations of blockchain present some wrong information!
- We don't have nearly enough time to do a deep dive into all the technical details.
  - These details are covered in the first half of my three-credit course: about twenty class hours.

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How does blockchain meet these requirements?

- A high-level overview will help frame the argument.
- I will do a “deep dive” in one specific area.
- Warning: frustration ahead!
  - I won’t have time today to answer questions about details of these technologies.

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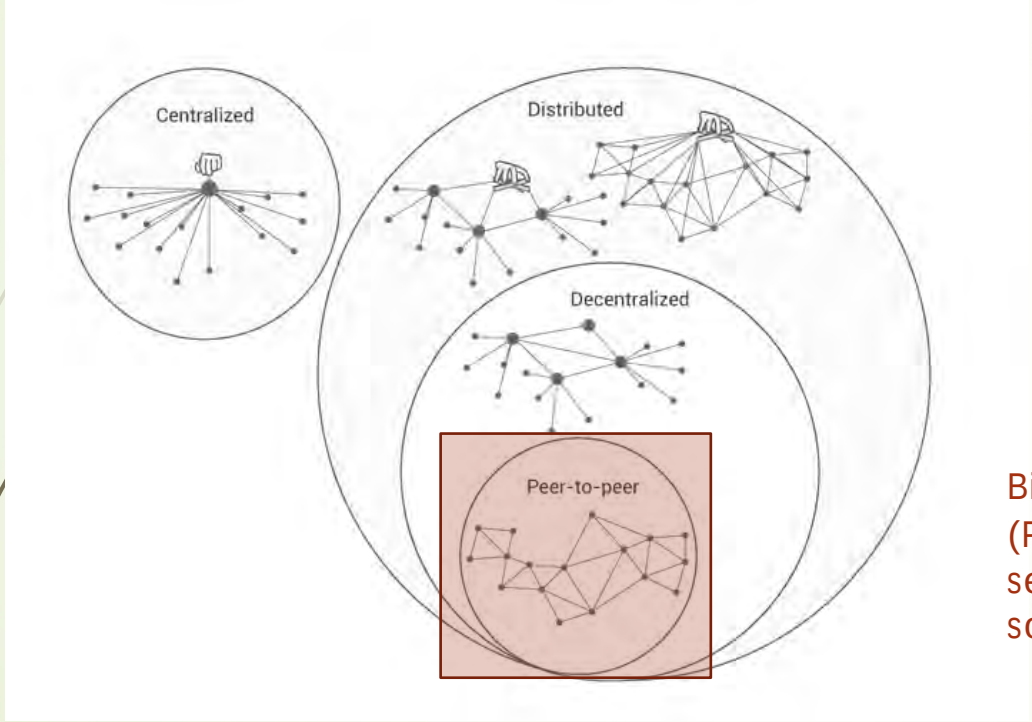
Types of networks



Source: https://medium.com/safenetwork/evolving-terminology-with-evolved-technology-decentralized-versus-distributed-7f8b4c9eacb

Bitcoin uses a peer-to-peer (P2P) network with no servers. All nodes are in some sense equal (peers).

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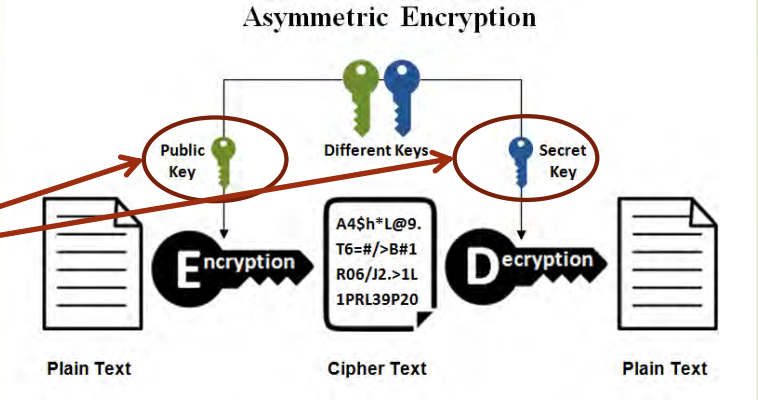
Public/private key encryption

- Invented in the 1970s
- Also called asymmetric encryption.
- Create two mathematically-related keys.
  - It's impossible to determine the private key from the public key.
- Alice publishes her public key to be used by anyone who wants to send her a secure message.
- Alice uses her private key to decrypt the message.



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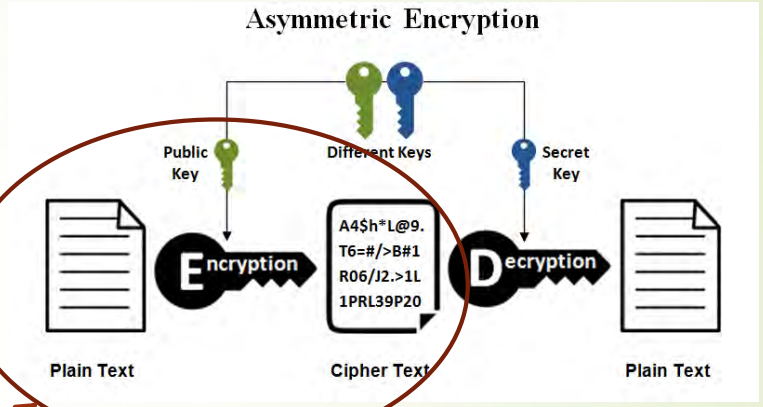

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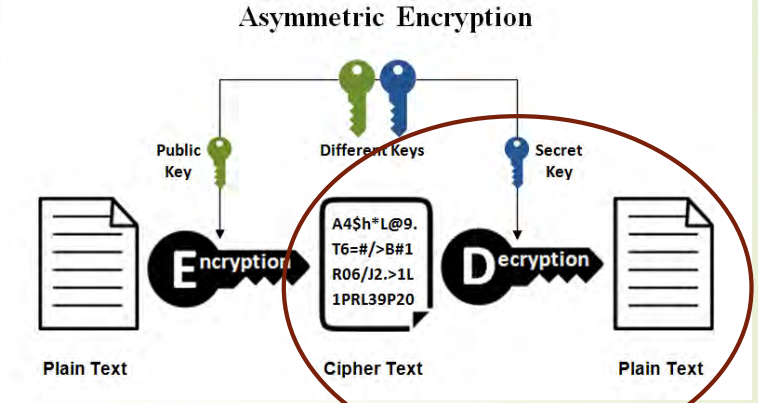

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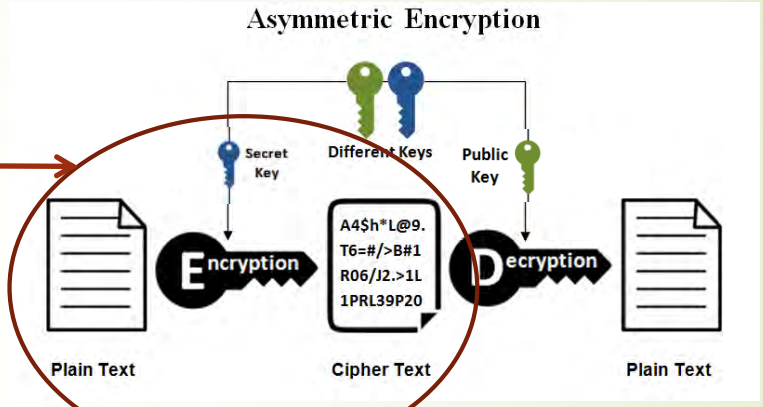
Public/private key encryption

- Alice can also encrypt a message with private key and decrypt it with public key.
- Why would Alice do this? Anyone with the freely available public key can decrypt the message!



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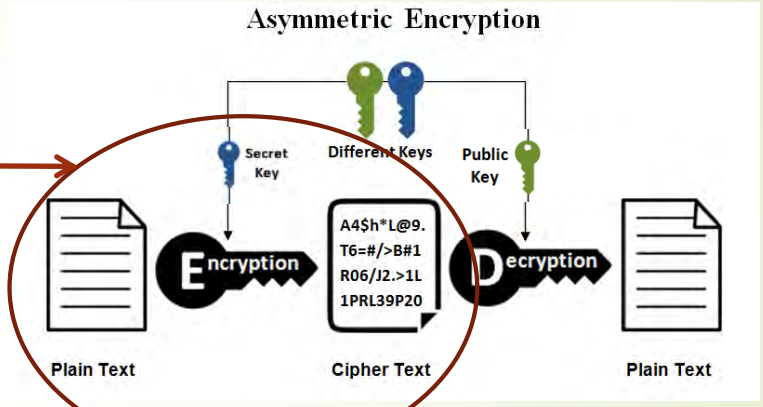
Public/private key encryption

- Alice can also encrypt a message with private key and decrypt it with public key.
- Why would Alice do this? Anyone with the freely available public key can decrypt the message!
- Allows Alice to securely sign a document, proving that it came from her.



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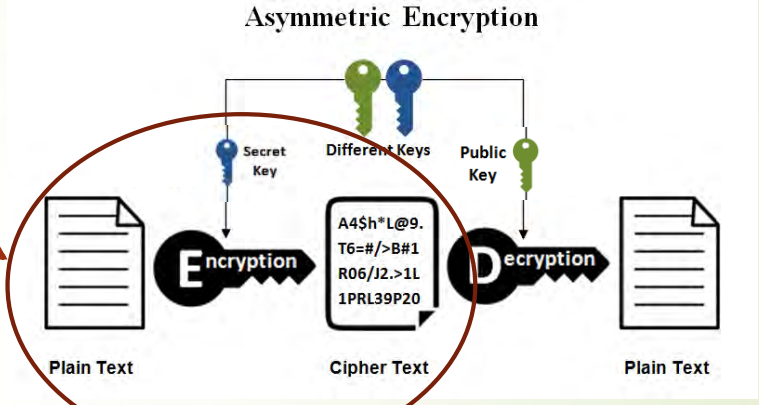
Public/private key encryption

- Alice uses her private key to securely sign a transaction to move her bitcoin to someone.



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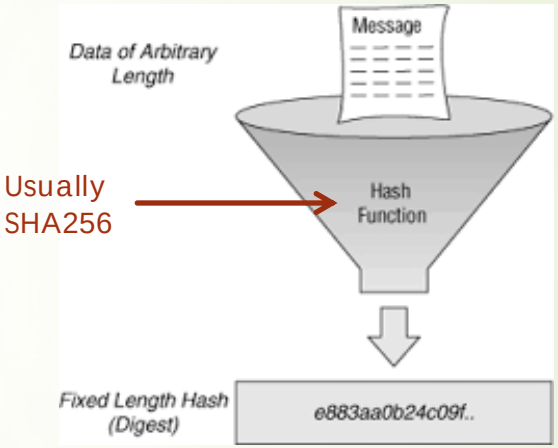
Hashing

- Take a message (string of bits) of arbitrary length.
- Mathematically transform it into a digital "fingerprint" (hash) of shorter and fixed length.
- Used in many places in Bitcoin.
- Bitcoin primarily uses a hash known as "SHA256."



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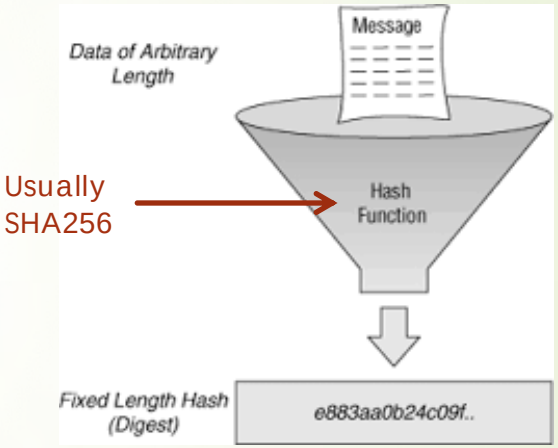
Hashing

- Hashing is irreversible.
- There are 2^256 possible hashes. This makes a collision (two different messages with the same hash) exceedingly unlikely in practice.
- Used in multiple places in Bitcoin.
- SHA256 is not predictable: there's no short-cut to obtaining the hash.



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Bitcoin transactions

- Most transactions move bitcoin from one or more input transactions to one or more output "addresses."
- Alice wants to send Bob 5 BTC.
  - She will take this amount from a previous transaction that moved bitcoin to her.
- Bob generates a private/public key pair.
- Bob hashes the public key and sends the hash to Alice as the "address" to which the bitcoin should be sent.
- Alice signs the transaction with her private key corresponding to the previous transaction.
  - If Alice looses the private key, she can never spend the bitcoin!

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A simple transaction: Alice sends bitcoin to Bob

- Input: pointer to an output of an earlier transaction
  - Transaction 123456, index 1
  - That output had delivered 8 BTC to Alice pseudonymously at "address" xxxxxx.
- Outputs
  - 5 BTC to Bob at address yyyyyy.
  - 2.99999 BTC "change" to Alice at a new address zzzzzz.
  - The remaining 0.00001 BTC is a transaction fee.
- Alice signs the input using her private key that corresponds to address xxxxxx.
- Note that Alice's original 8 BTC were consumed.

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Bitcoin transactions

- Average size is about 250 bytes.
  - Very rarely over 900 bytes.
- Some other proposed uses would need to store much more data.
- This is yet another issue to consider.

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Bitcoin wallets

- Transactions are generally initiated through client "wallet" software.
  - The wallet holds bitcoin addresses and corresponding private keys (proof of ownership)
  - Wallets can be a significant potential point of weakness in the Bitcoin structure.

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Blockchain

- Shared public ledger that contains all verified Bitcoin transactions
  - Only wallet clients maintain spendable *balances*. They are not stored on the blockchain.
- The integrity of the blockchain is enforced by cryptography and group consensus among the nodes on the network.

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Adding transactions to the blockchain

- A miner is a full node on the Bitcoin network.
  - Not all full nodes are miners.
- Miners assemble transactions into blocks.
- Miners compete to add the next block of transactions to the blockchain.
  - Until August 2017, there was a 1 MB limit on block size.
  - May ignore a transaction if its fee is too low.
  - By design, a new block is added about every ten minutes.

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Adding transactions to the blockchain

- Miner collects a reward (12.5 BTC since July 9, 2016) and any transaction fees.
  - Reward was initially 50 BTC.
  - Reward is halved every 210,000 blocks or about every four years.
  - A “satoshi” is the smallest unit of bitcoin that currently can be spent.
    - 1 BTC = 100,000,000 satoshis
  - Estimate is that reward will go to zero in 2140, because you can’t have less than one satoshi as the reward.
- 21 million BTC will have been mined by 2140.

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What's in a block?

- Header
  - Hash of previous block
  - Hash of "all transactions" in the block
  - Other fields
- Transactions
- Hash of this block that incorporates
  - Hash of previous block
  - Hash of "all transactions"
  - Proof of work: solution to a difficult puzzle

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Adding transactions to the blockchain

- Proof of work: solving a difficult puzzle
  - Find a number, called a “nonce.”
  - Hash the nonce, the hash of the prior block, some other header data, and the hash of all transactions in the current block.
  - The resulting hash has must have a numeric value less than a number called the “difficulty” of the proof of work.
    - The difficulty is adjusted periodically to keep the time between successive blocks about ten minutes.
  - Requires enormous computing power.

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Adding transactions to the blockchain

- When a miner solves the puzzle, it broadcasts the new block to the network.
- Each other full node verifies the entire block.
  - Verifies each transaction in the block.
  - Verifies the hash for the new block.
  - If verified, adds the block to its local copy of the blockchain and rebroadcasts the block.
  - If verification fails, the node simply ignores the new block.

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How a miner creates new bitcoins

- "Coinbase" transaction
  - First transaction in a block
  - Created by miner to collect the block reward (new bitcoin, currently 12.5 BTC) and transaction fees
  - No inputs
  - Includes arbitrary data

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Genesis block

- First block in the blockchain
- Created by Satoshi Nakamoto
- Has only a single, coinbase transaction
- Refers to a January 3, 2009 article in the *London Times*: "Chancellor on brink of second bailout for banks."
- The first 50 bitcoins are unspendable.
  - 16 additional bitcoins have since been sent to this unspendable address as tributes to Satoshi Nakamoto.

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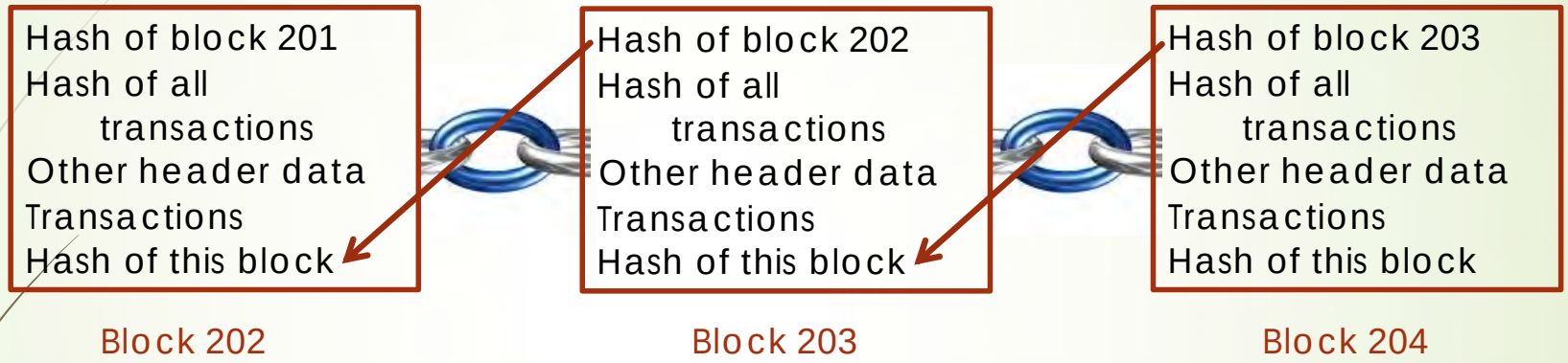
How blockchain works



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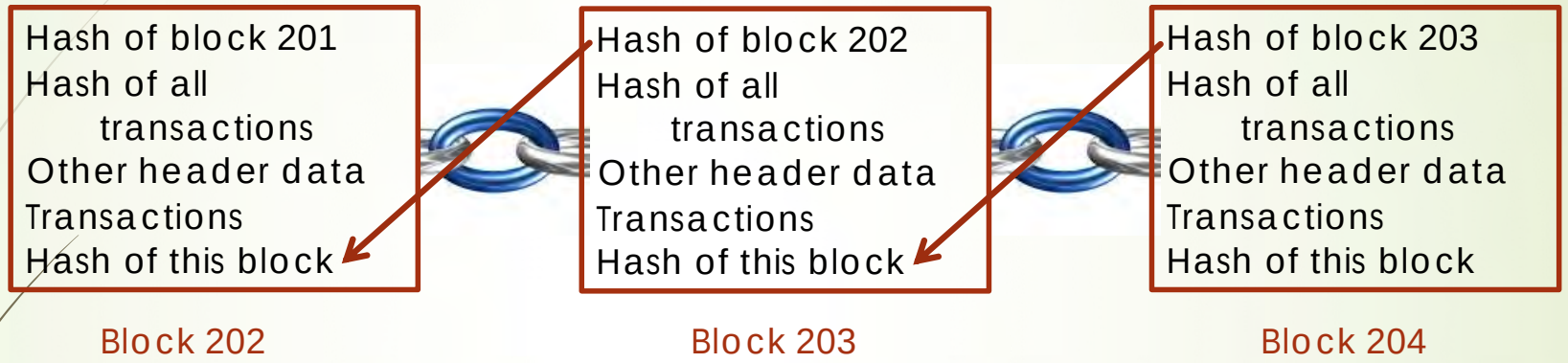

A transaction is changed in block 202. ➡ The hash of all transactions in block 202 won't match. ➡ The hash of block 202 is wrong. ➡ The hash of block 203 is wrong. ➡ The hash of every subsequent block is wrong.

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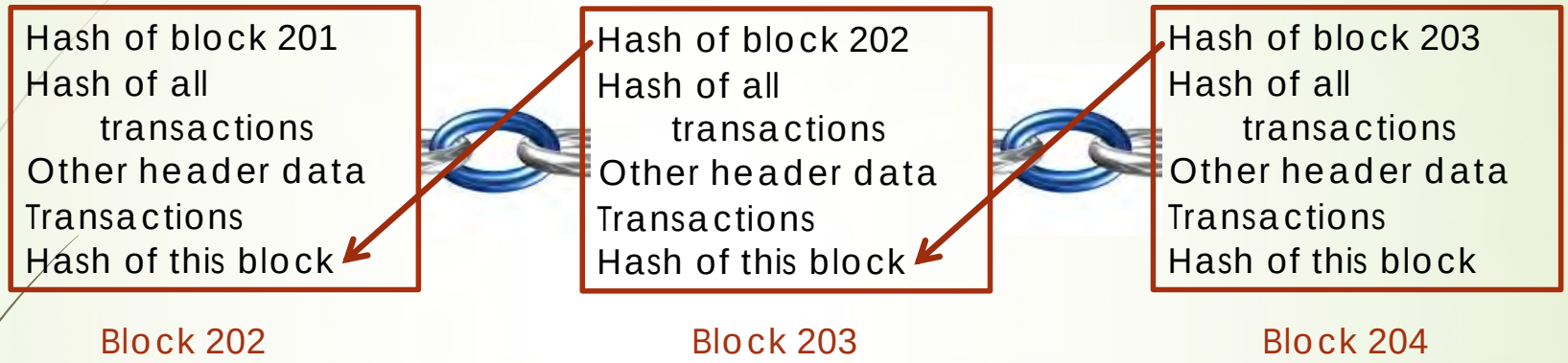
How blockchain works



A transaction is changed in block 202. ➡ The hash of all transactions in block 202 won't match. ➡ The hash of block 202 is wrong. ➡ The hash of block 203 is wrong. ➡ The hash of every subsequent block is wrong.

How will the transaction change be detected?

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How will the transaction change be detected?

- The blockchain is *not* immutable. Rather, any change is readily detectable.
- But will the change actually be detected?
- Heads up: This is an important question that should be considered further.

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Gee, blockchain is really fast!

- Here's the hash of an old transaction. This hash is used as the transaction ID (txid).
  - 287d49a84bef4eeb087d6288b3cc63543243bb81dd614be8f0d7c51b1598deae
- Let's find this transaction on blockchain.info.
- Transaction details come up immediately.

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Gee, blockchain is really fast!

- When a new transaction is broadcast to the network, all full nodes verify it.
  - One step is checking to make sure the bitcoin in the input has not already been spent.
- This verification appears to happen quickly.

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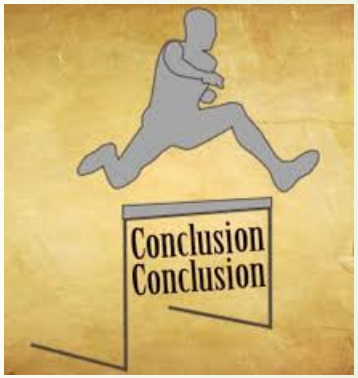
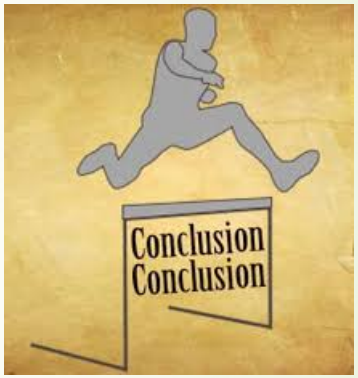
Jumping to a conclusion

- If we can quickly find a transaction by its txid and if we can quickly determine whether a new transaction is a double-spend, then we can quickly retrieve any data from the blockchain.



Jumping to a conclusion

- If we can quickly find a transaction by its txid and if we can quickly determine whether a new transaction is a double-spend, then we can quickly retrieve any data from the blockchain.
- Hold on! Is this conclusion justified?



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Structure of the Bitcoin database

- Currently, about 180 GB
- Contains four types of data
  - The actual blocks of data
  - blocks/index: metadata about each known block, including a pointer to where the block is stored
    - Optionally includes an index to all transactions in the block
  - chainstate: compact representation of all current utxo's and some metadata about the transactions that created them.
    - Utxo: Unspent transaction output
    - Sufficient to check for double-spending
  - blocks/rev: undo data to remove a block from the chain

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Why the database structure matters to us

- We're doing a deep dive here.
- Technical details are important when evaluating proposed blockchain use cases.
  - There are so many technical details.
  - It's a challenge to know which details might impact suitability for a specific application.
    - You have to understand *all* the details.

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Why the database structure matters to us

- "Blocks/index" lets you quickly locate a specific transaction by its txid.*
  - *Transaction indexing is optional.
- "Chainstate" lets you quickly determine whether a new transaction is a double-spend.
- Searching through the block history for other purposes is probably very time-consuming.
  - Locating non-indexed data can be very slow.

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Consider using Bitcoin to maintain vital statistics

- Births, deaths, marriages
- Accept for now that this application is possible on Bitcoin's blockchain.
- Consider this query: How many people born after January 1, 1998 have been married?
  - How this query would be processed using the blockchain?
  - Modern databases have evolved to process such queries efficiently.
    - Physical data storage techniques
    - Multiple index tables

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Consider using Bitcoin to maintain vital statistics

- Consider this query: How many people born after January 1, 1998 have been married?
- It would be very time-consuming to run this query on the blockchain.
  - You'd have to go through every block starting with the first block that has data from 1998.

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You need a strong understanding of how blockchain works to evaluate proposed use cases.

- My current research
  - How does SegWit ("Segregated Witness"), adopted in August 2017, impact this discussion?
    - Effectively allows a larger block size
    - Supports "second layer protocols
      - Smart contracts
      - Lightning Network: small, recurring payments off-chain

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You need a strong understanding of how blockchain works to evaluate proposed use cases.

- My current research (continued)
  - What other characteristics of Bitcoin's blockchain may limit its suitability for other uses?
  - Do other versions of blockchain, specifically Ethereum and Hyperledger Fabric, overcome these limitations?

Keep a healthy skepticism.

- Blockchain was designed to meet the specific needs of a cryptocurrency.
  - The “cypherpunk” distrust of central authority is fundamental.
  - Many proposed uses differ significantly from Bitcoin.
- Many proposed uses would need efficient querying of the blockchain database.
  - That’s not how blockchain in Bitcoin was designed.

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Is blockchain mostly hype?

- *The need exists for a shared, trusted ledger that supports processing smart transactions.*
- This probably will happen and be hugely impactful.
- But blockchain is just one possible approach to meeting this need.

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Thanks for participating!

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