Introduction to Blockchain Technology

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Introduction

"To understand the power of blockchain systems, and the things they can do, it is important to distinguish between three things that are commonly muddled up, namely the bitcoin currency, the specific blockchain that underpins it and the idea of blockchains in general."

The Trust Machine, THE ECONOMIST, Oct. 31, 2015

Blockchain terminologies

- **Blockchain – What is it?**
  - Aka DLT (Distributed Ledger Technology) - rudimentary shared accounting system
  - Technologically, it is :
    - Distributed database – public ledger (you can insert, select data, but **can't** update or delete data.
    - Distributed computer – execute digital contracts
    - Based on **p2p** (peer-to-peer) technology, cryptology and API

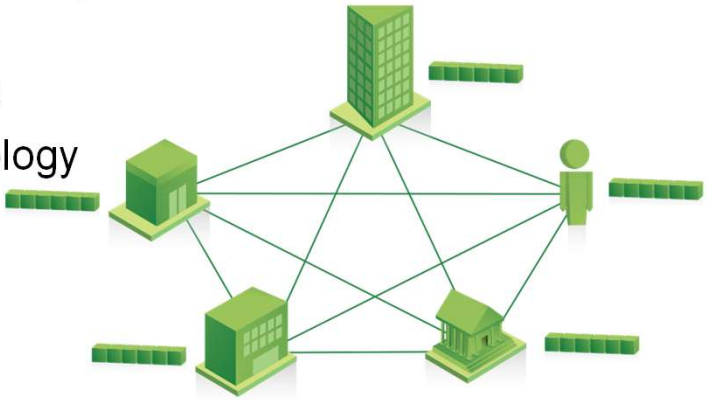


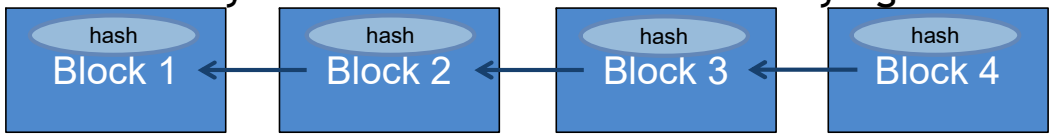
Image source: https://www.ibm.com/blockchain/assets/images/landing/blockchain_shared_ledger.png

Blockchain terminologies

- **Blockchain - What is it?**

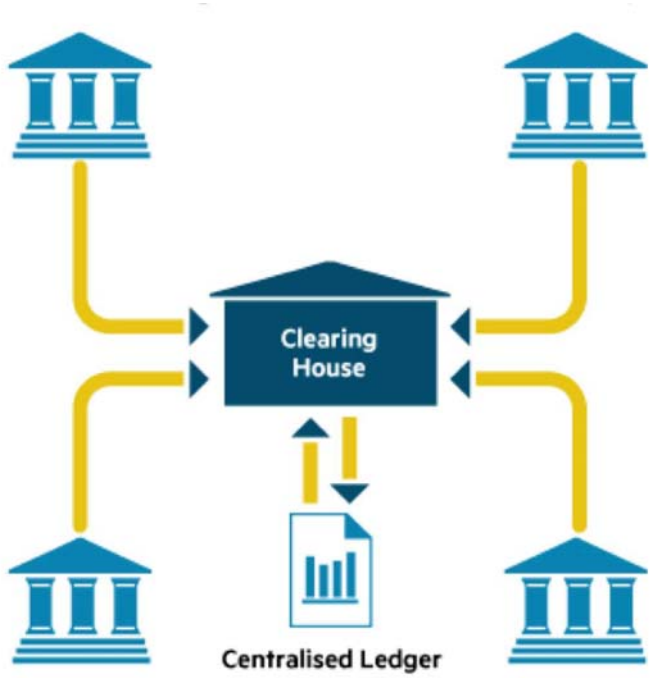
  In fact, the blockchain is more than a technology, it

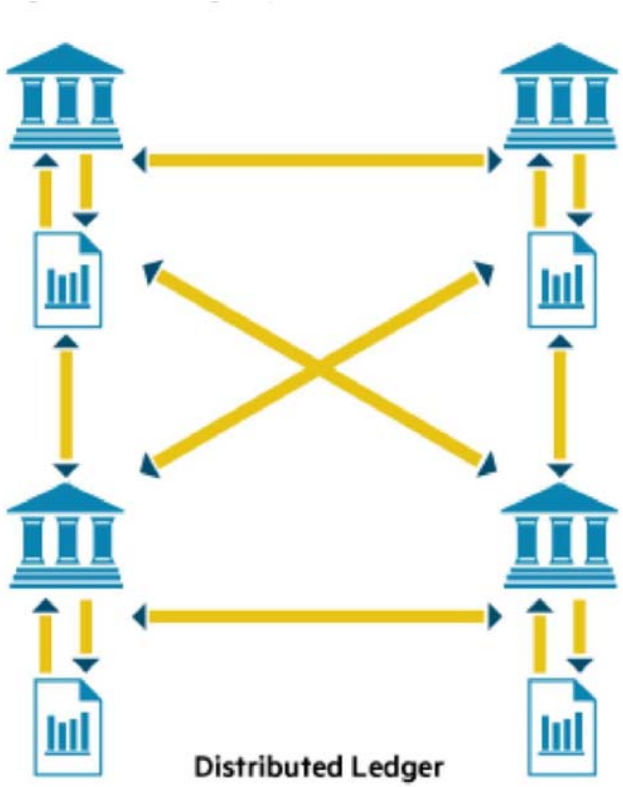
  - Usually contains financial transactions
  - Is replicated across a number of systems in almost real-time
  - Uses cryptography and digital signatures to prove identity, authenticity and enforce read/write access rights
  - Can be written by everyone in a public blockchain (but only certain participants in a private blockchain)
  - Can be read by participants, often a wider audience
  - Has mechanisms to make it hard to change historical records, or at least make it easy to detect when someone is trying to do so



Blockchain terminologies

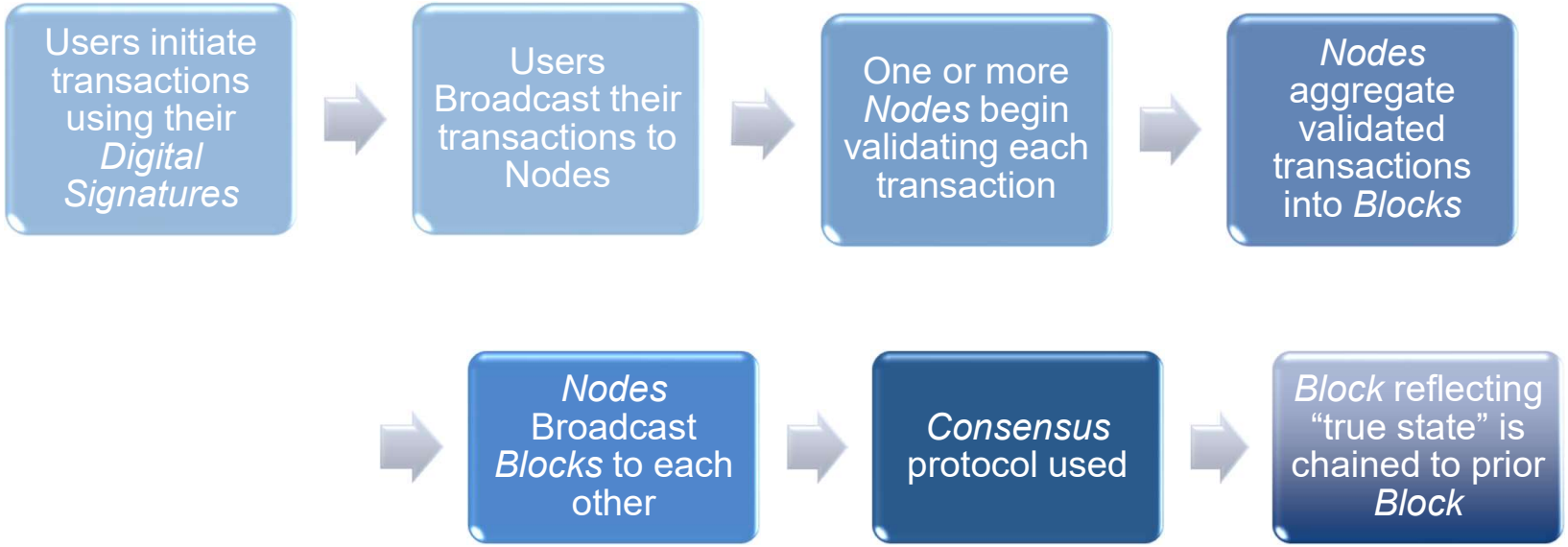
- **Distributed ledger – What is it?**





Blockchain terminologies

- **Distributed ledger – How it works?**



Blockchain terminologies

- **Transaction & blocks**
  - A transaction is a value transfer; a block is a collection of transactions on the bitcoin network, gathered into a block that are hashed and added to the blockchain.

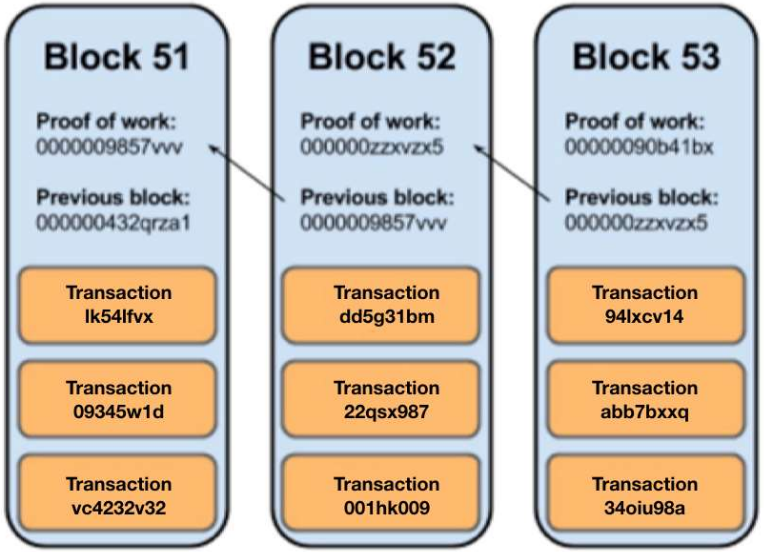
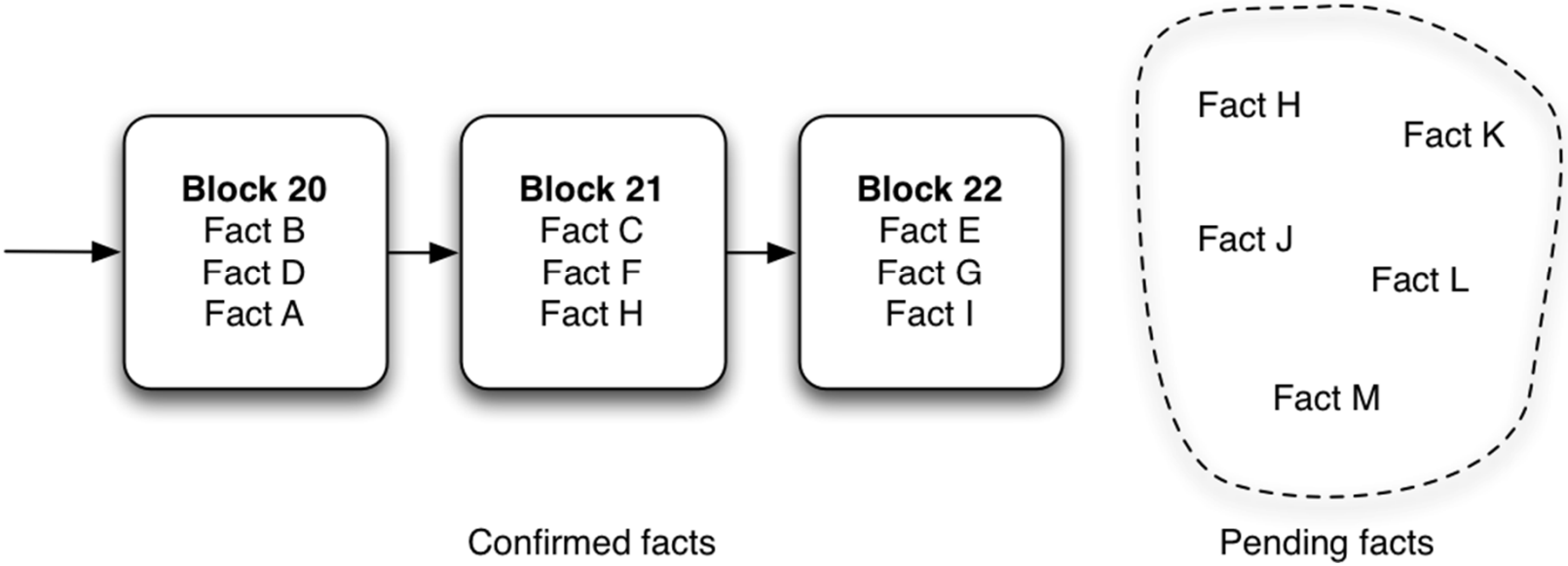


Image source: https://pplware.sapo.pt/informacao/monero-xmr-uma-moeda-segura-privada-e-sem-rasto/

Blockchain terminologies

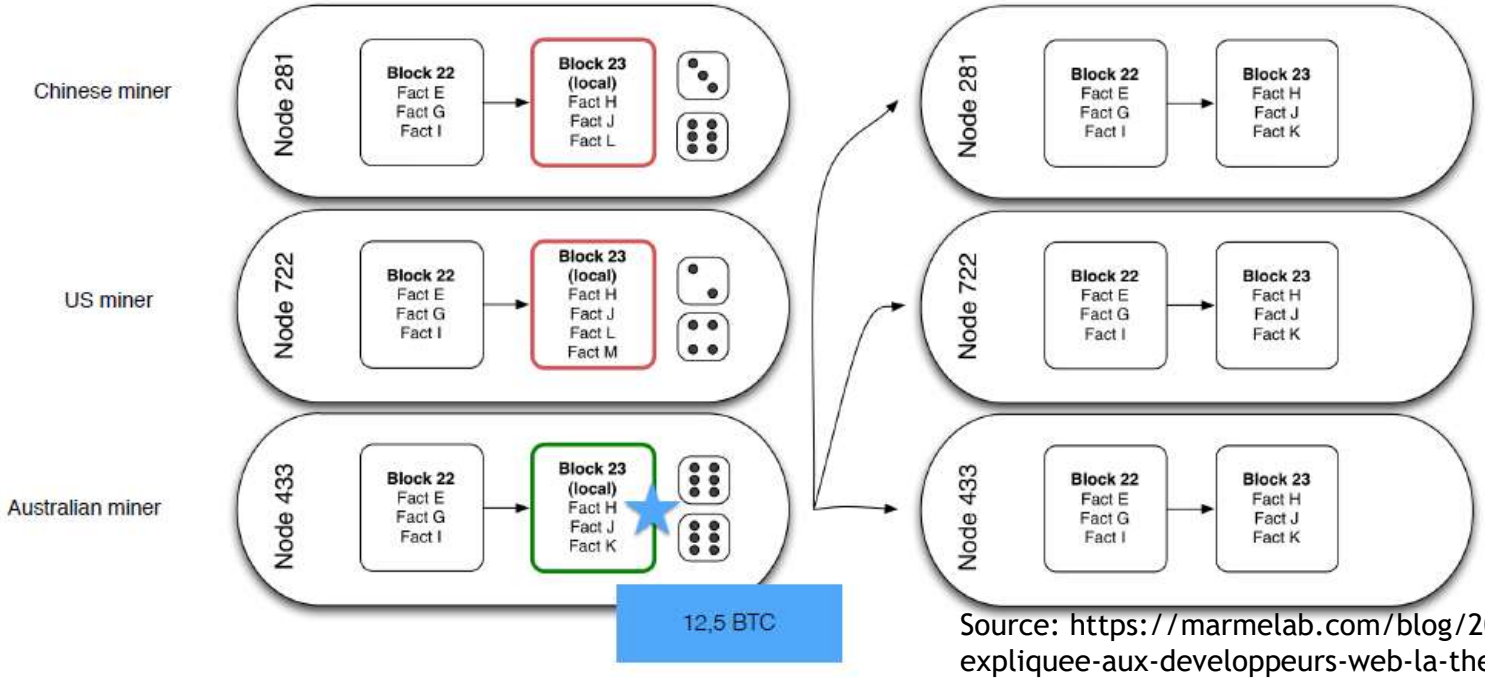
- **Mining**
  - This process of solving cryptographic problems using computing hardware also triggers the release of cryptocurrencies



Source: https://marmelab.com/blog/2016/05/12/blockchain-expliquee-aux-developpeurs-web-la-theorie.html

Blockchain terminologies

- **Mining**
  - The process by which transactions are verified and added to a blockchain.



Source: https://marmelab.com/blog/2016/05/12/blockchain-expliquee-aux-developpeurs-web-la-theorie.html

Blockchain terminologies

- **Mining**
  - Miners on the network select transactions from pools and form them into a ‘block’.

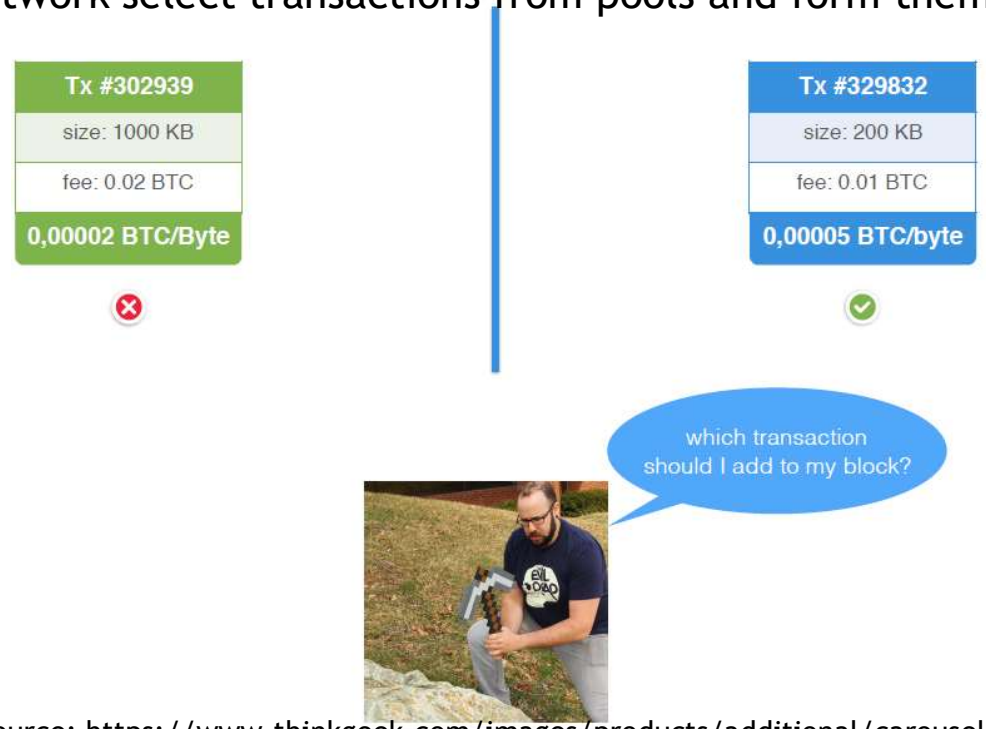


Image source: https://www.thinkgeek.com/images/products/additional/carousel/e847_minecraft_pickaxe_inuse.jpg

Blockchain terminologies

- **Forks**
  - A fork is the creation of an ongoing alternative version of the blockchain, by creating two blocks simultaneously on different parts of the network. This creates two parallel blockchains, where one of the two is the winning blockchain.
  - When does it happens?
    - Block found at the same time
    - Software incompatibility
    - “We don’t agree” split

Source: https://medium.com/my-blockchain-bible/101-blockchain-terminology-874f007c0270

Blockchain terminologies

- **Forks**

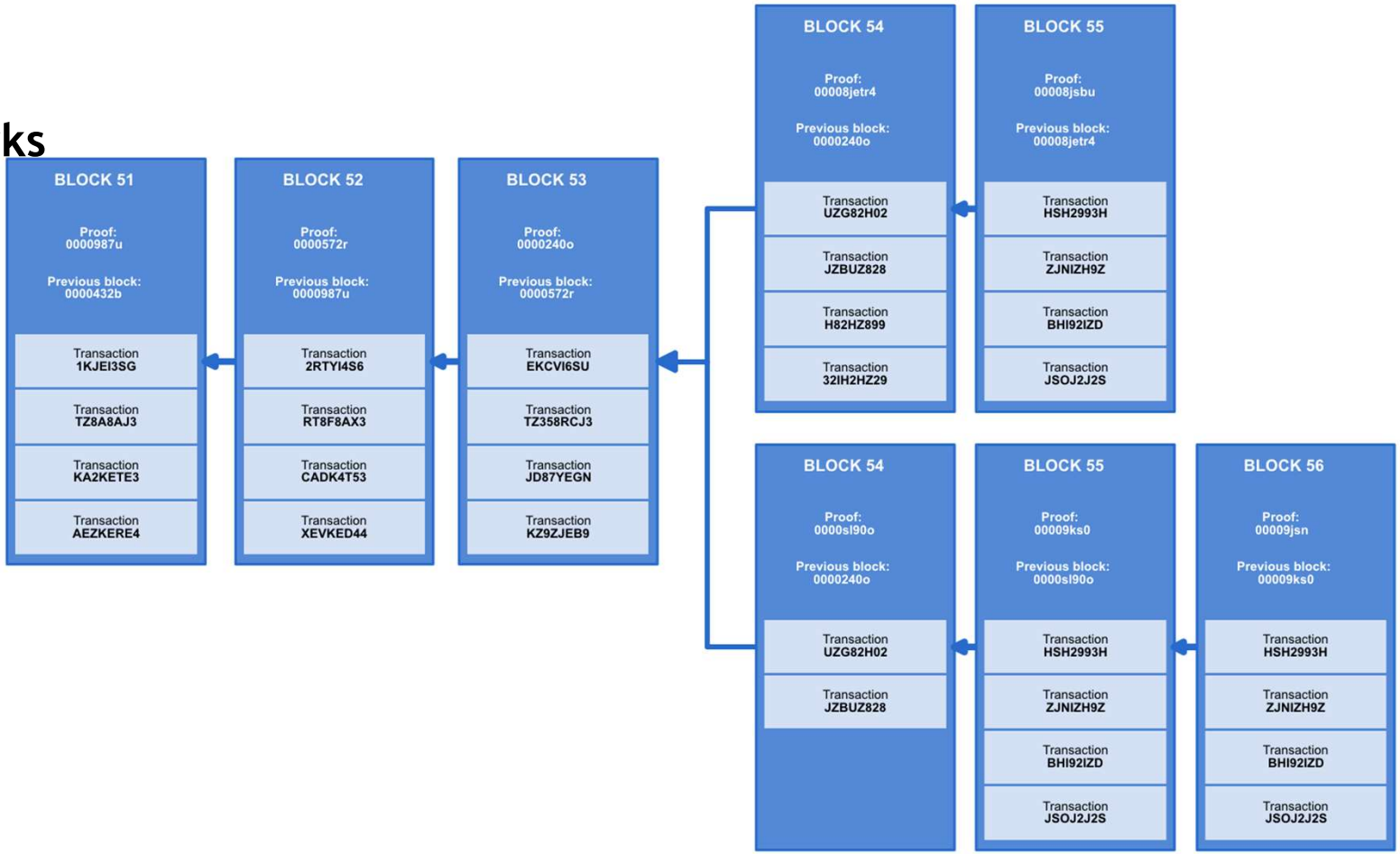


Image source: Scorechain

Blockchain terminologies

- **Bitcoin**
  - Crypto currency, first asset based on Blockchain
  - Used for drug/weapons e-commerce, ransom ware
  - Used for remittance, speculation, store of value

"What is needed is an electronic payment system based on cryptographic proof instead of trust, allowing any two willing parties to transact directly with each other without the need for a trusted third party."

Satoshi Nakamoto – October 31st, 2008

Source: https://medium.com/@flatoutcrypto/what-is-the-point-of-eos-ad385740b05f

Blockchain terminologies

- **Bitcoin**
  - Monetary creation

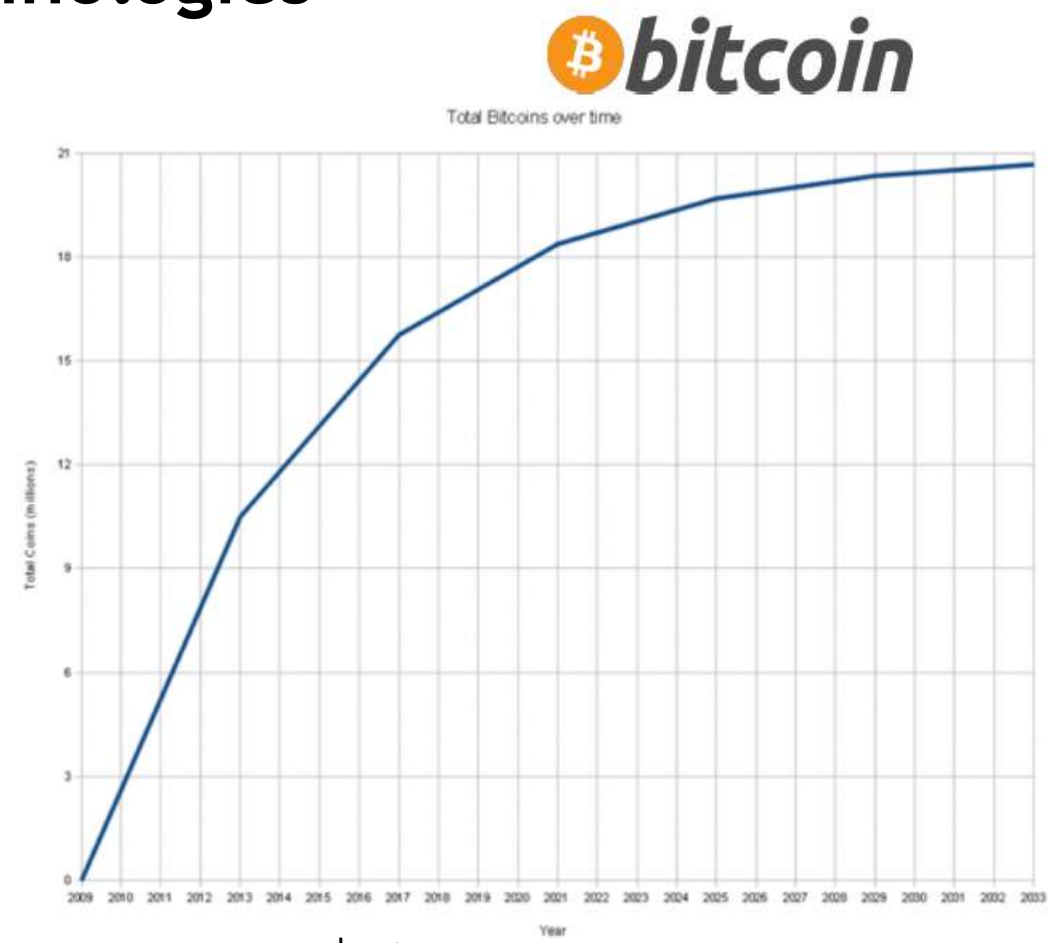
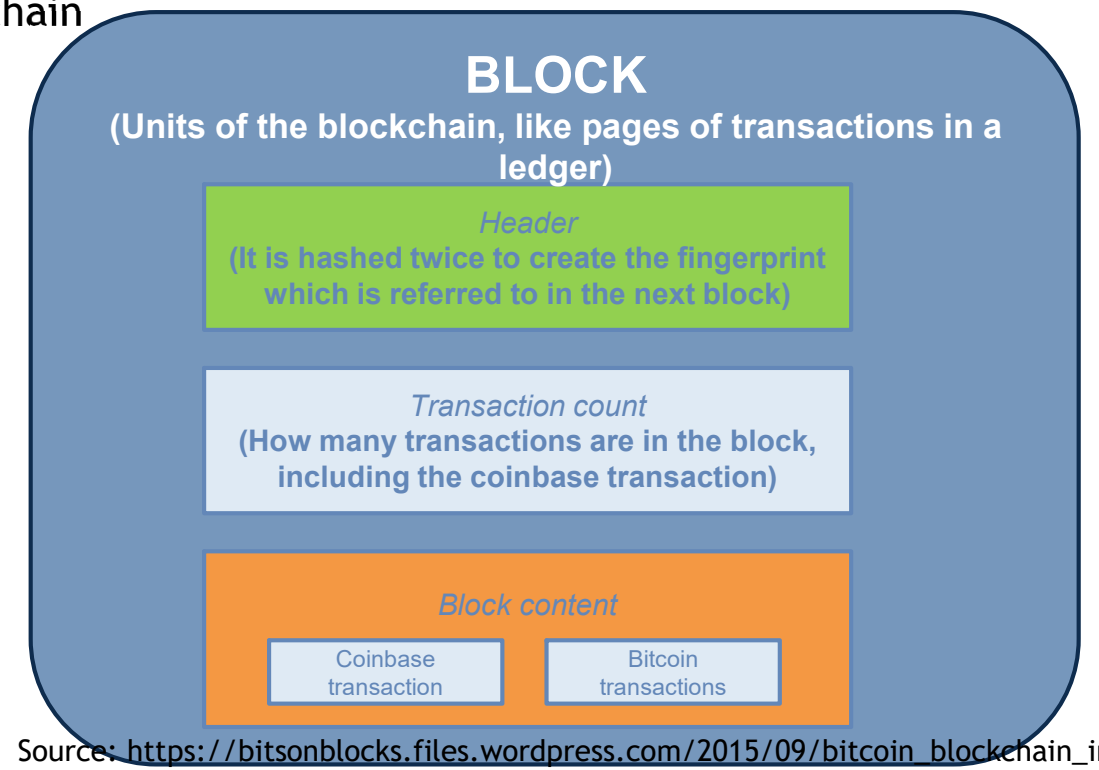


Image source: https://upload.wikimedia.org/wikipedia/commons/thumb/5/54/Total_bitco

Blockchain terminologies

- **Bitcoin**
  - Inside Bitcoin's Blockchain



Source: https://bitsonblocks.files.wordpress.com/2015/09/bitcoin_blockchain_infographic1.jpg

Blockchain terminologies

- **Bitcoin**
  - Inside Bitcoin's Blockchain

  - *Block Header* : includes Technical data, Previous block hash, Merkle Root, Timestamp, Difficulty target, Nonce. Here is an example:

bitcoin

Height	448909
Block time	2017-01-19 09:32:58
Trades sum	5,340.87080329 BTC
Nb txs	1637
Difficulty	336,899,932,795.81
Fee	0.41239309 BTC
Hash	0000000000000000000dbc2853f4939baad1f09d086fa68a0105d79378bf7629
Version	127
Confirmations	1
Merkle root	a4772eff88cbe645bba832d31730f0b42ea4d8d05d02ea62be533316bd3fb197
Prev block hash	0000000000000000015278f089845eaa41753e61a0f97c54b364325ca74a6275
Size	947.32 kB
Coin days destroyed	2,913.95

Source: https://bitsonblocks.files.wordpress.com/2015/09/bitcoin_blockchain_infographic1.jpg
Image source: www.blockchain.com

Blockchain terminologies

- **Bitcoin**
  - Inside Bitcoin's Blockchain

  - *Block content* : Transaction Flow

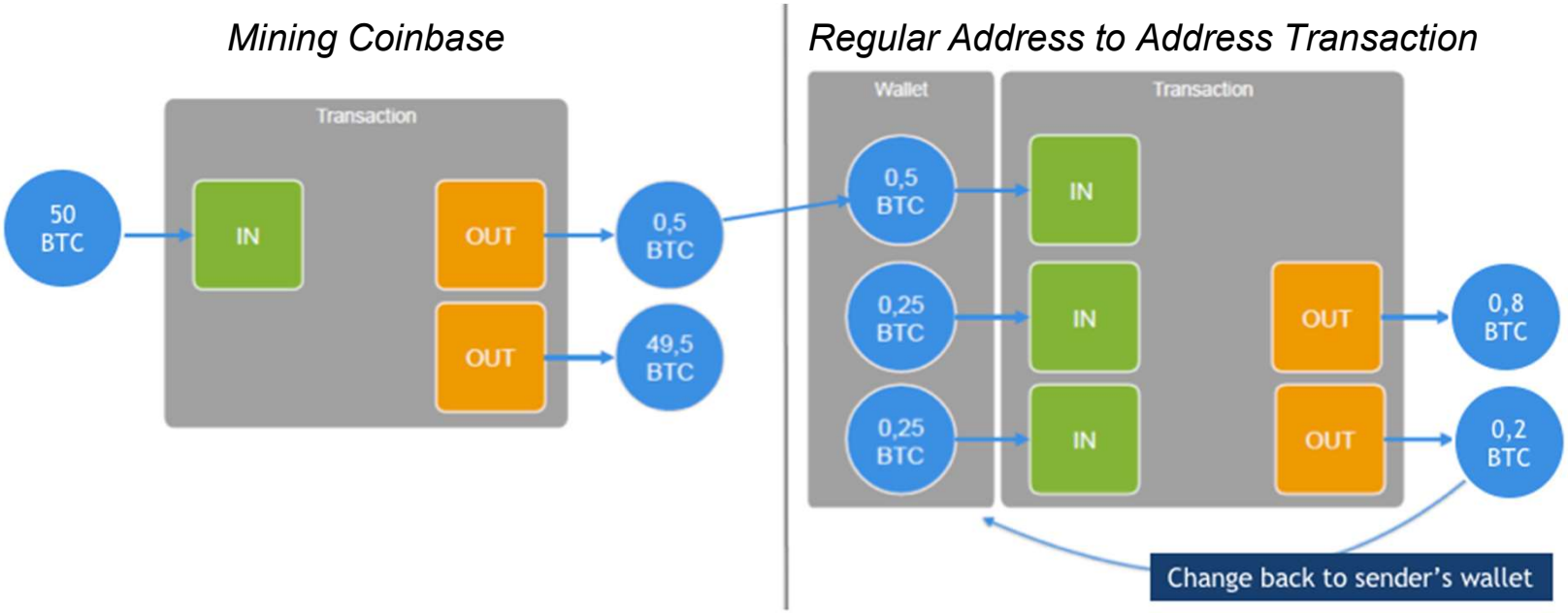
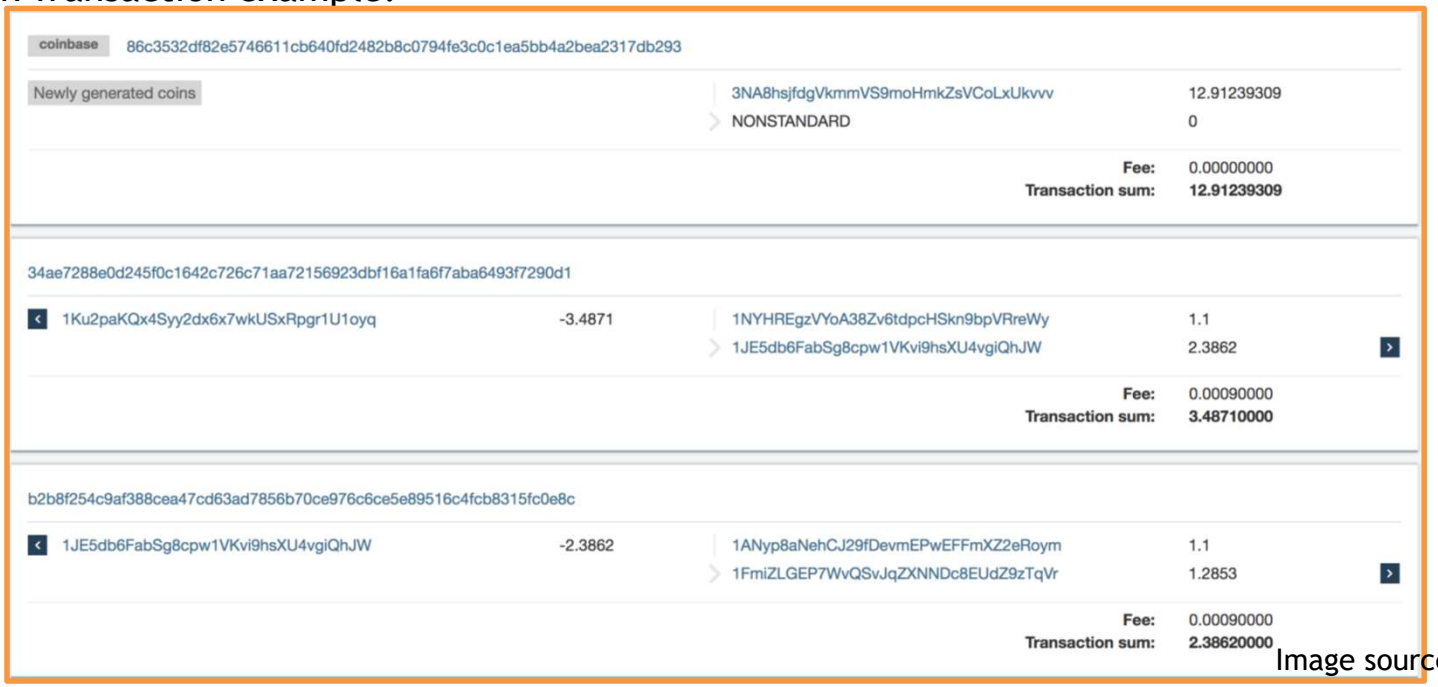


Image source: Scorechain

Blockchain terminologies

- **Bitcoin**
  - Inside Bitcoin's Blockchain

  - Block Transaction example:



coinbase 86c3532df82e5746611cb640fd2482b8c0794fe3c0c1ea5bb4a2bea2317db293			
Newly generated coins		3NA8hsjfdgVkmmVS9moHmkZsVCoLxUkvvv	12.91239309
		NONSTANDARD	0
		Fee:	0.00000000
		Transaction sum:	12.91239309
34ae7288e0d245f0c1642c726c71aa72156923dbf16a1fa6f7aba6493f7290d1			
1Ku2paKQx4Syy2dx6x7wkUSxRpgr1U1oyq	-3.4871	1NYHREgzVYoA38Zv6tdpcHSkn9bpVRreWy	1.1
		1JE5db6FabSg8cpw1VKvi9hsXU4vgiQhJW	2.3862
		Fee:	0.00090000
		Transaction sum:	3.48710000
b2b8f254c9af388cea47cd63ad7856b70ce976c6ce5e89516c4fcb8315fc0e8c			
1JE5db6FabSg8cpw1VKvi9hsXU4vgiQhJW	-2.3862	1ANyp8aNehCJ29fDevmEPwEFFmXZ2eRoym	1.1
		1FmiZLGEP7WvQSvJqZXNNDc8EUdZ9zTqVr	1.2853
		Fee:	0.00090000
		Transaction sum:	2.38620000

Image source: www.blockchain.com

Blockchain terminologies

- **Bitcoin**
  - How the money transfer works

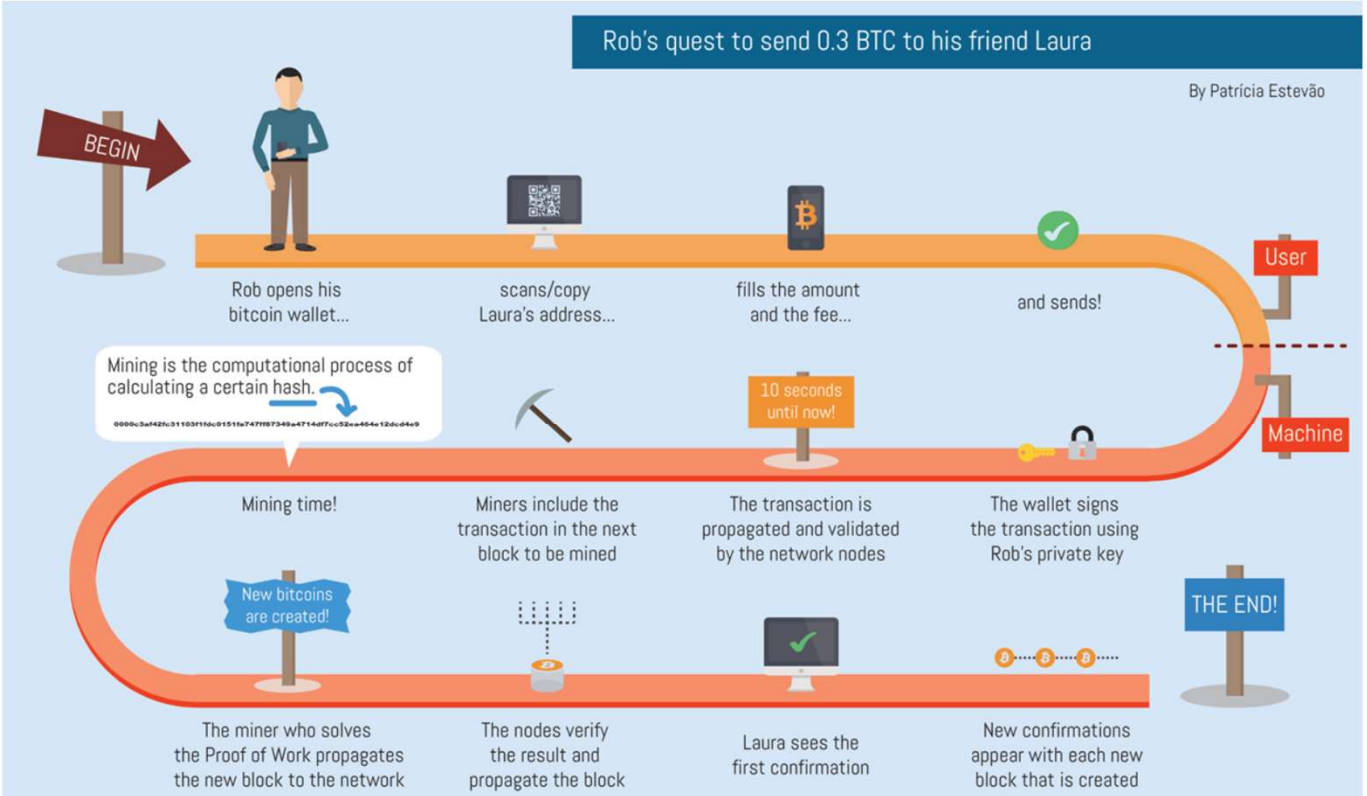


Image source: https://www.weusecoins.com/images/bitcoin-transaction-life-cycle-high-resolution.png

Blockchain terminologies

- **Ethereum**
  - Proposed in late 2013 by Vitalik Buterin (cryptocurrency researcher and programmer)
  - Online crowdsale during summer 2014
  - Bitcoin on steroids!

"A blockchain is a magic computer that anyone can upload programs to and leave the programs to self-execute, where the current and all previous states of every program are always publicly visible, and which carries a very strong cryptoeconomically secured guarantee that programs running on the chain will continue to execute in exactly the way that the blockchain protocol specifies."

VitalVitalik Buterin

Source: https://medium.com/blockchain-review/how-does-the-blockchain-work-for-dummies-explained-simply-9f94d386e022
Image source: https://znews-photo-td.zadn.vn/w660/Uploaded/lce_uxlcq/2017_06_27/20DBBITCOIN4master675.jpg

Blockchain terminologies

- **Ethereum**
  - Decentralised app platform (dapps)
  - Transaction & smart-contracts ledger
  - Based on the Ethereum Virtual Machine (EVM)
  - Cryptocurrency called ether (ETH)

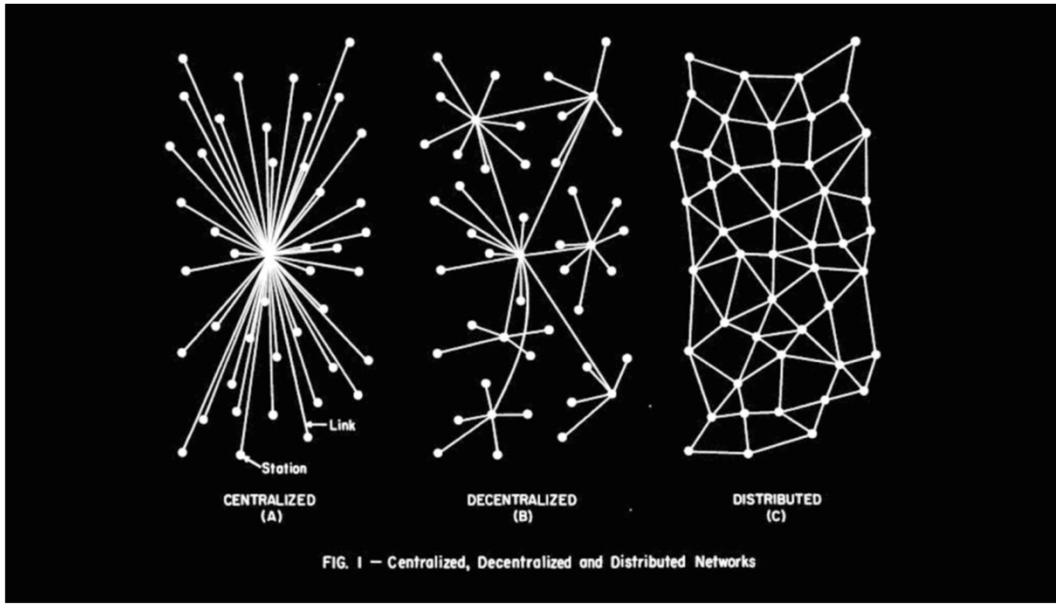
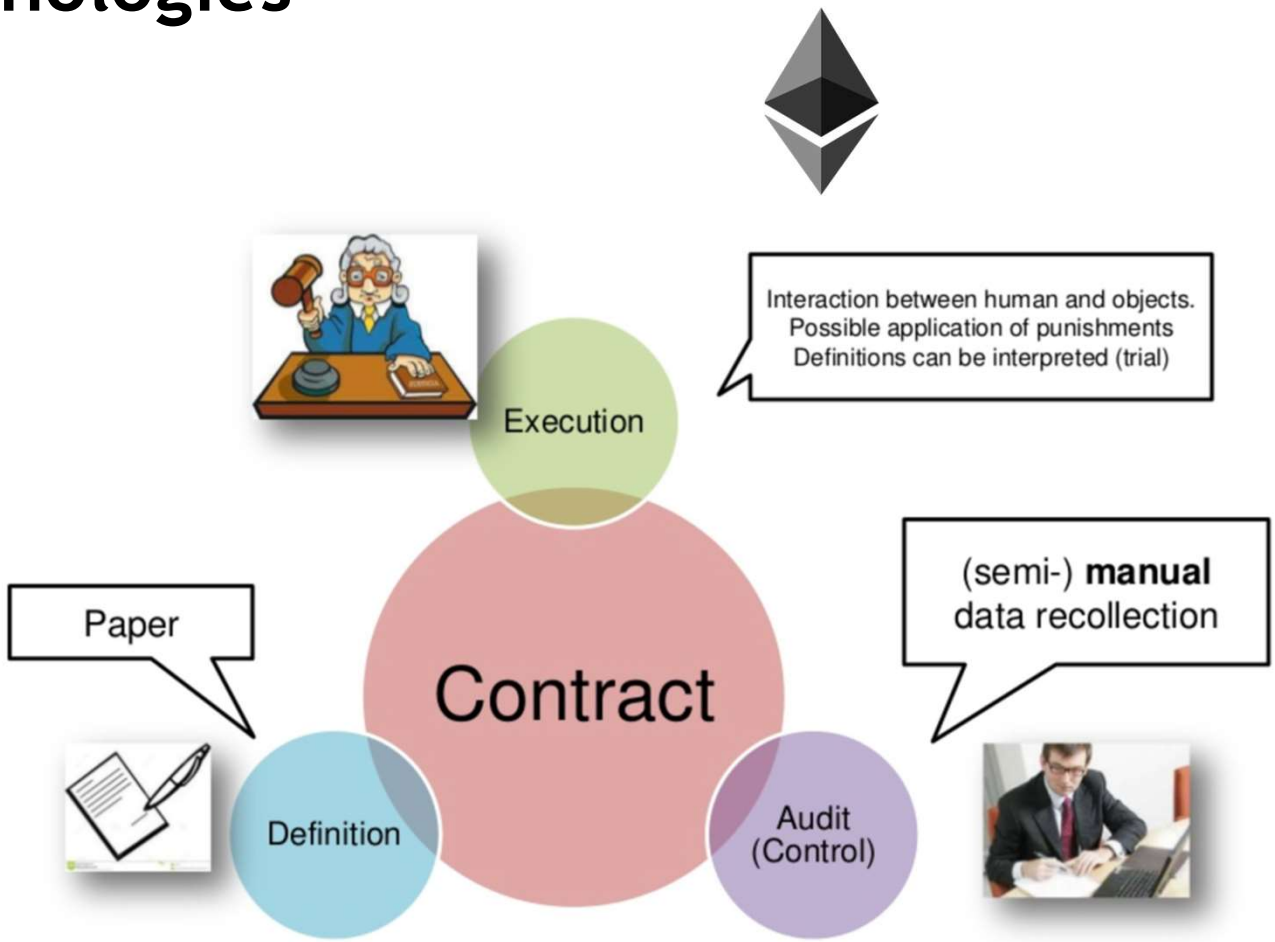


Image source: https://image.slidesharecdn.com/empresaeinovaonasociedadeemredemaro2013-130717064842-phpapp01/95/empresa-e-inovao-na-sociedade-em-rede-84-638.jpg?cb=1374043787

Blockchain terminologies

- **Ethereum**
  - *Smart Contract*

How a “Traditional” contract works:

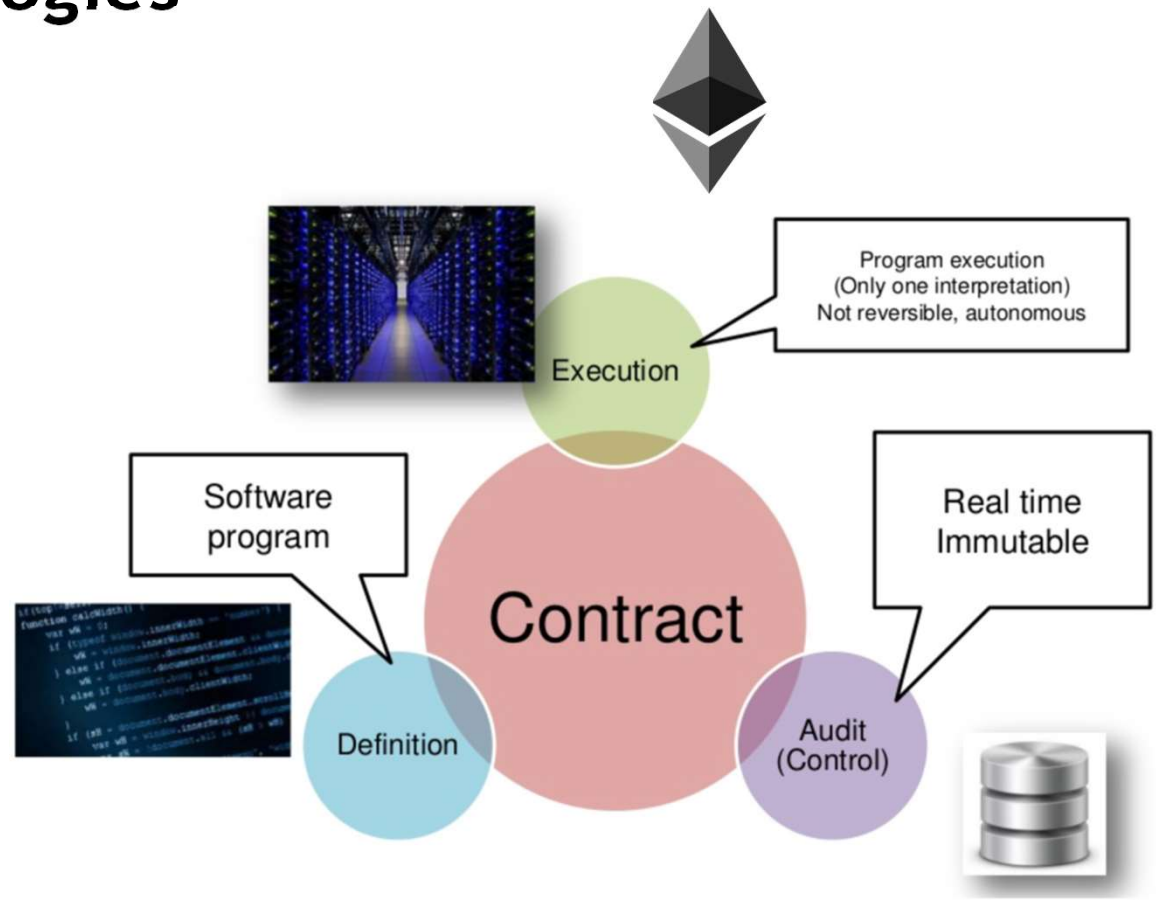


Source: https://www.investopedia.com/terms/s/smart-contracts.asp
Image source: https://image.slidesharecdn.com/smart-contracts-150925125324-lva1-app6892/95/smart-contracts-4-638.jpg?cb=1443185644

Blockchain terminologies

- **Ethereum**
  - *Smart Contract*

How a "*Smart Contract*" contract works:



Source: https://www.investopedia.com/terms/s/smart-contracts.asp/

Image source: https://image.slidesharecdn.com/smart-contracts-150925125324-lva1-app6892/95/smart-contracts-5-638.jpg?cb=1443185644

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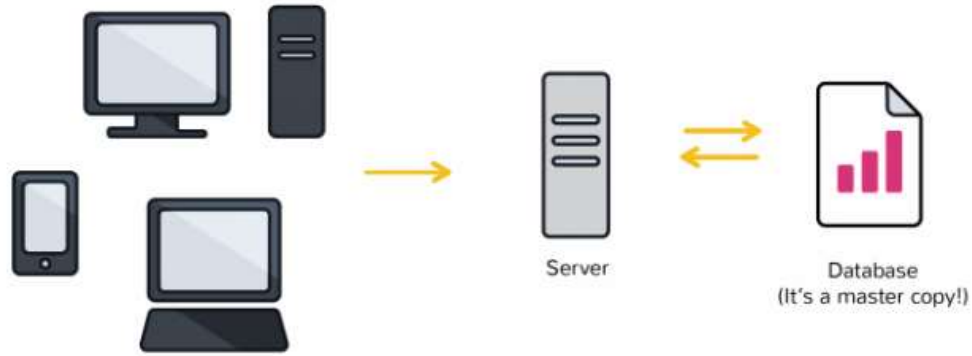
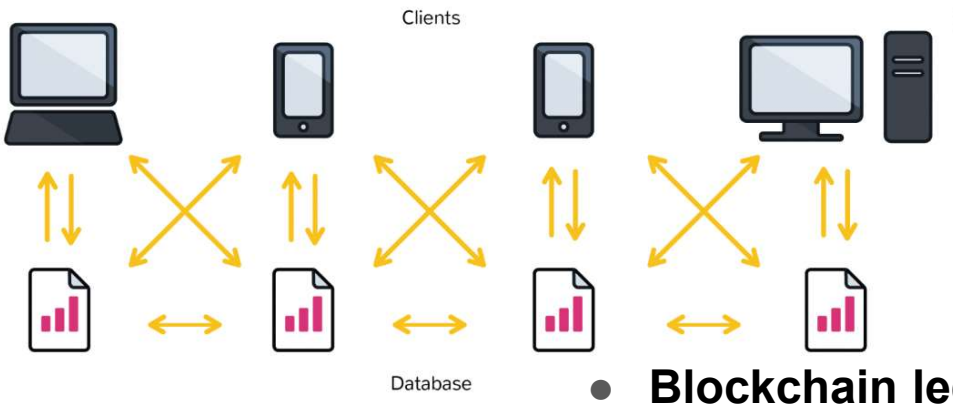
Distinction between databases and blockchain ledgers

- **Distinction between databases and blockchain ledgers**
  - *It begins with architecture*



- **Databases**



- **Blockchain ledgers**

Source: https://www.coindesk.com/information/what-is-the-difference-blockchain-and-

Distinction between databases and blockchain ledgers

Databases	VS	Blockchains
Databases have admins & centralized control		No on is the admin or in-charge
Only entities with rights can access database		Anyone can access (public) blockchain
Only entities entitled to read or write can do so		Anyone with right proof of work can write on the blockchain
Databases are fast		Blockchains are slow
No history of records & ownership of digital records		History of records & ownership of digital records

Source: https://coinsutra.com/blockchain-vs-database/

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Cryptography, hash functions and digital signatures

- **Cryptography**: the encryption and decryption of data
  - 2 main cryptographic concepts used in Blockchain:
    - Hashing
    - Digital Signatures

  - 3 forms of encryption that are widely used:

Symmetric cryptography	Asymmetric cryptography	Hashing
Same password to encrypt & decrypt	one password to encrypt, the other to decrypt	Maps to fixed size
2 ways function	Passwords come by pair	1 way function

Source: https://lisk.io/academy/blockchain-basics/how-does-blockchain-work/what-is-hashing
https://lisk.io/academy/blockchain-basics/how-does-blockchain-work/digital-signatures

Cryptography, hash functions and digital signatures

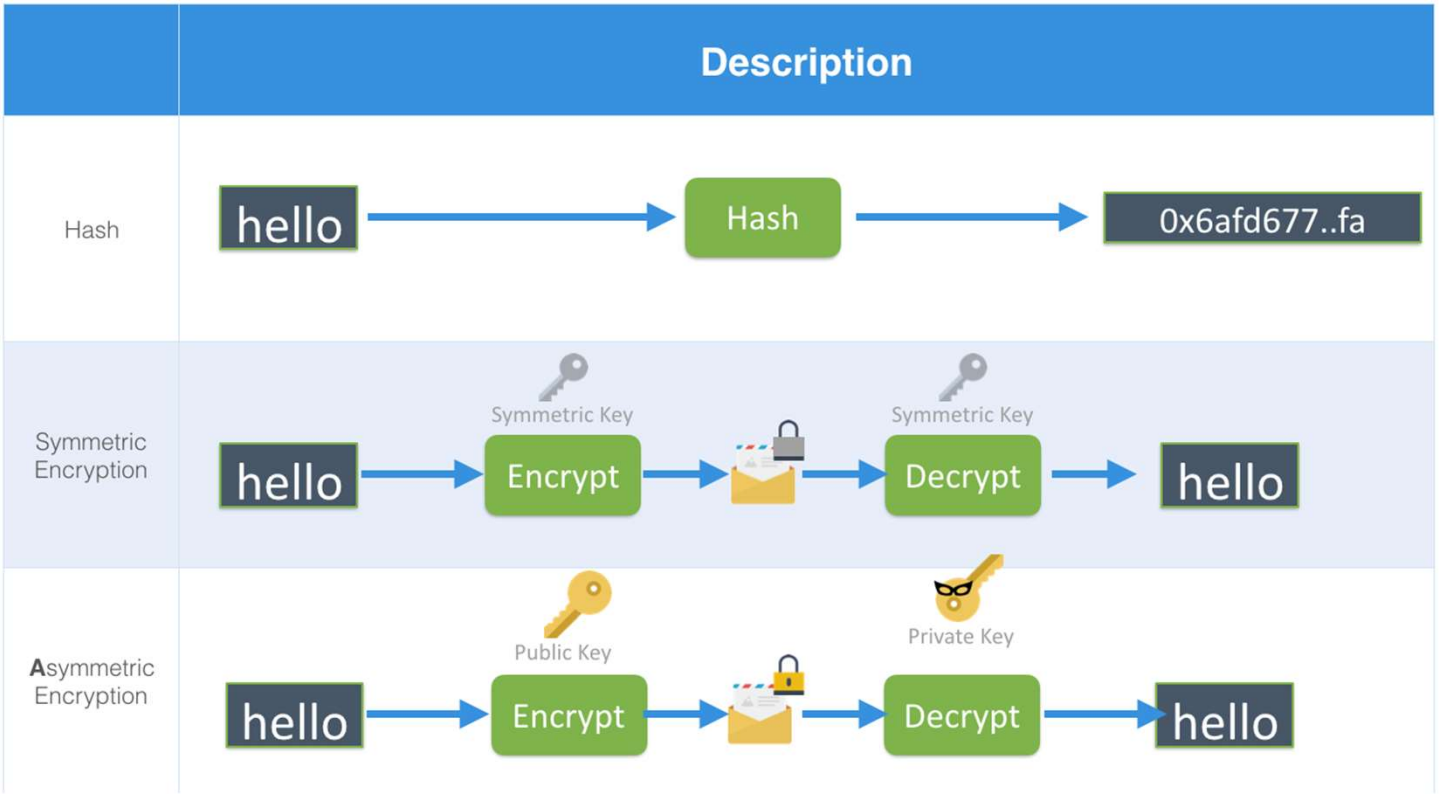

Image source: Scorechain

Cryptography, hash functions and digital signatures

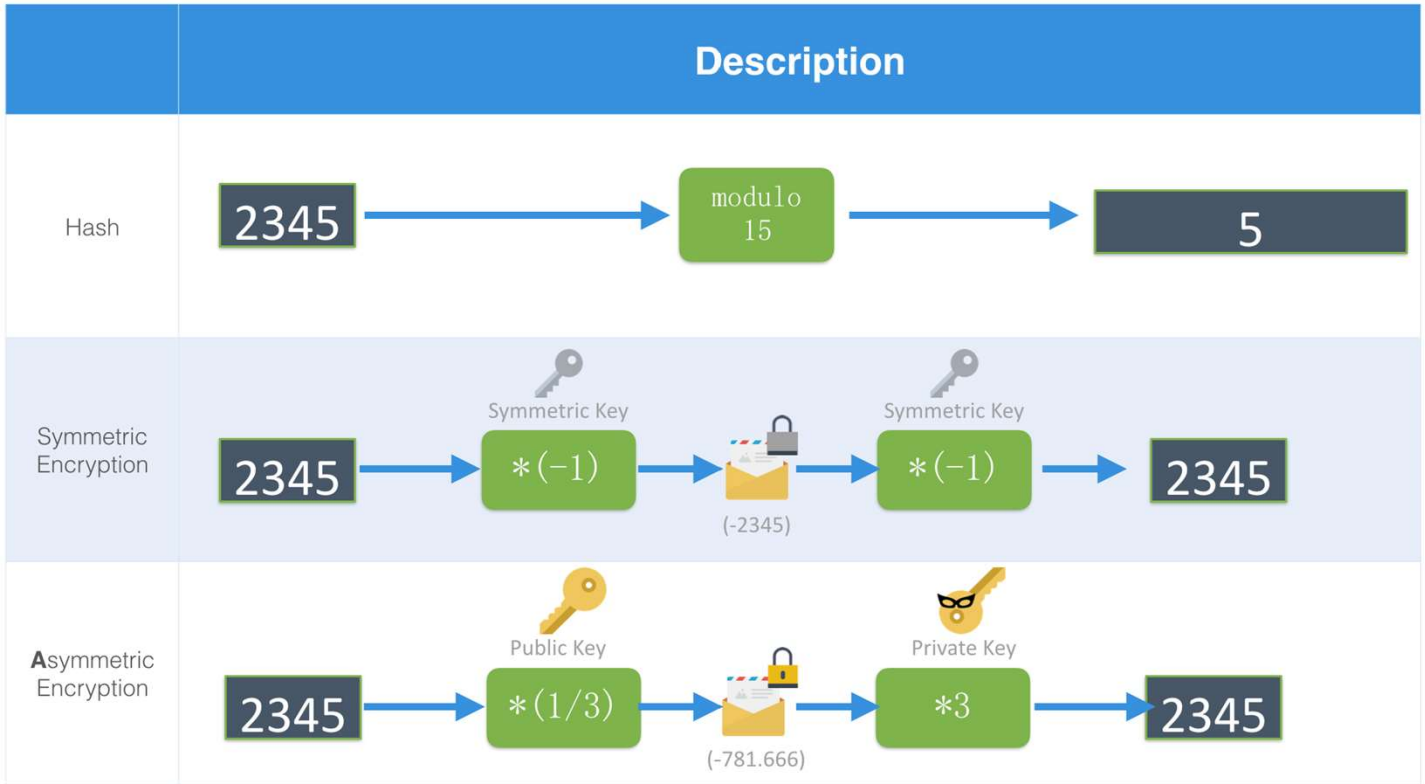

Image source: Scorechain

Cryptography, hash functions and digital signatures

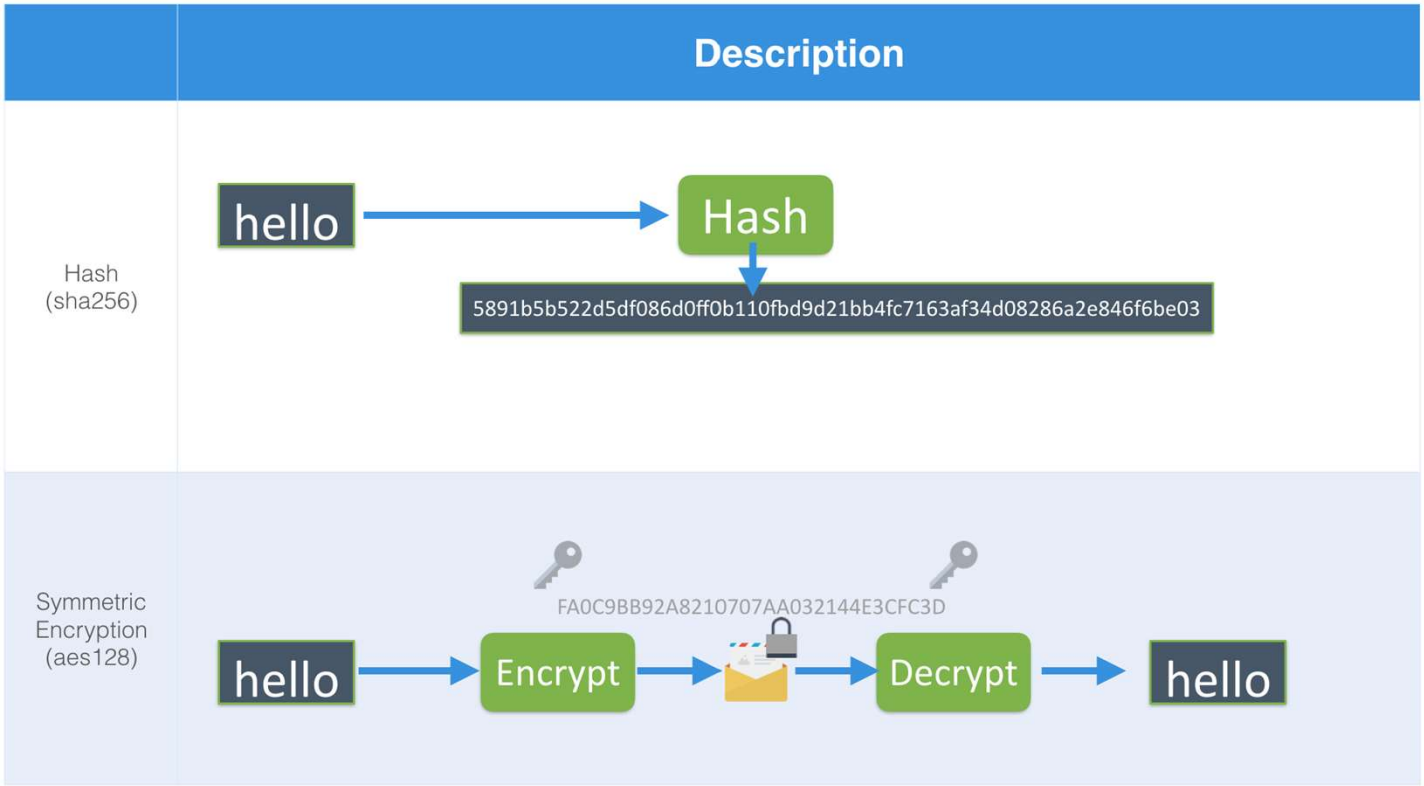

Image source: Scorechain

Cryptography, hash functions and digital signatures

	Description	
Asymmetric Encryption		
Asymmetric Encryption (RSA 1024)	-----BEGIN RSA PRIVATE KEY----- MIICXQIBAAKBgQCISsEbRdh3GzlrfF4OFCApmVzzTWBYucXKgjs18XQ9B7peqtXj 9CeJxQTTXfpRjDkM+k6TCDrlyRhffrN7zAqSSmfFreIYHa37VE8XFZfP5UOyJv3W bwHJXGp0AAkHXr3bokh3Sgj4RFBdVvIBIFvumapQLn7Oze0kE37Je3kf2QJDAQAB AoGAIuoroCX7dz/DUXqRyb+EIcQFGNsopHIq5l8IdiA96+iP6PKQys3gVx3ex5sa pktqzhVNjcMc+4LRuJ0Hs94oksO3aKIG248vODjf2PYTKINKLcHG5HmLUbaK8uCi GRJ+bxd1AGtH7ioyDcfseRhMItjQY1DSGGkg6sA1niS/AQECQQDAijCzzV4xlsWz onVk54V0gTkz4wUHvlZcheWfpZoy7yW1LO0zbH3XfCJbsKKagnY/vqQaA99uU6cO 8tBrOt5hAkEAtTaUR8Zr+isCspb7WZ7Dv0t5yfiFbkfeA0Cl7QJ7hptJA+66KUUC KV5BoUXHBGAfqYrgGm+aKevcPXZUm3yEeQJBALV+ThRfJUhXWHtRS5nXSAyfdx17 BRXcjKngqahlwUb7+S6EcAAGZ8VFRVnq8gv1qKPEAApp1ia4ggRsTJyXvGECQCik BvlZ7Nl8T+yRo+Ijj+8ZFEVRsUscXxRHqW7R05xKs0NohOPAkE2K0BIFNu8qR6+U b9I9+UsxIIFMSolckbECQQCvin3KbC8lBeretn5mOR8CVxUnxU42vk4E0EhJzy8q eWxZmTdqLWfcgm1M3dLIQCdbk15GDNKYSywdZxbF05Zz -----END RSA PRIVATE KEY-----	-----BEGIN PUBLIC KEY----- MIGfMA0GCSqGSIb3DQEBAQUAA4GNADCBiQKBgQCISsEbRdh3GzlrfF4OFCApmVzz TWBYucXKgjs18XQ9B7peqtXj9CeJxQTTXfpRjDkM+k6TCDrlyRhffrN7zAqSSmfF reIYHa37VE8XFZfP5UOyJv3WbwHJXGp0AAkHXr3bokh3Sgj4RFBdVvIBIFvumapQ Ln7Oze0kE37Je3kf2QJDAQAB -----END PUBLIC KEY-----
Asymmetric Encryption (secp256k1)	8ab2da1ed39fad3491ceb556b6bf2e124822614f6987056e07345f2b068a12fb	04e17e467d8f78110bea2ae18c8fa1a6963202d8ee9845c86080cb8ae5b5a 558ad279ae57e0b56259470f92021a2dccb0f7ceb68c88f25b13bce9f2c0e9c8adb8c

Image source: Scorechain

Cryptography, hash functions and digital signatures

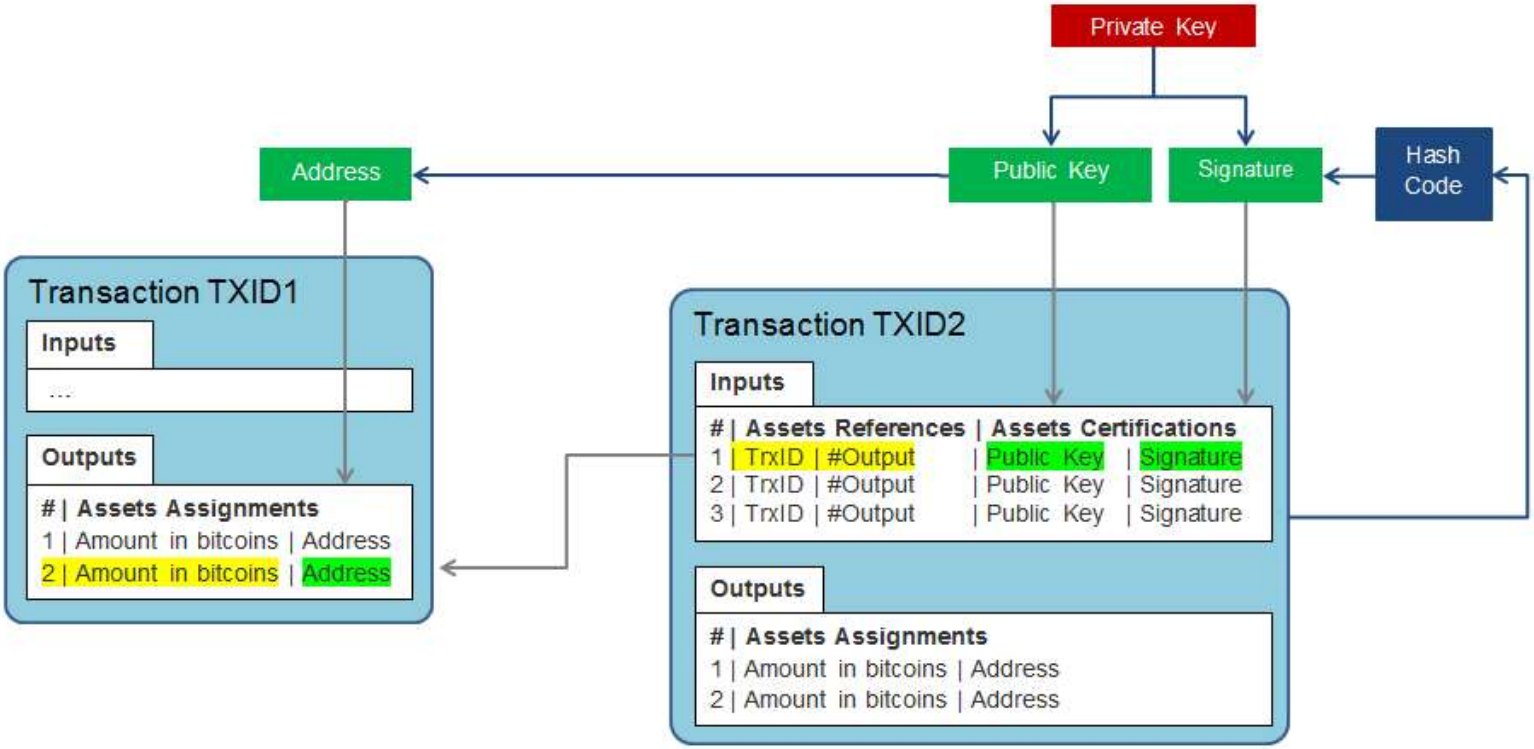

Image source: https://pascalpares.gitbook.io/an-introduction-to-the-bitcoin-system/the-transactions/structure-of-a-transaction

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Consensus components

- **Principles and paradigms of distributed systems**
  - ***Byzantine fault tolerance*** (BFT): the dependability of a fault-tolerant computer system, particularly distributed computing systems, where components may fail and there is imperfect information on whether a component has failed.
  - The objective of BFT is to defend against failures of system components with or without symptoms that prevent other components of the system from reaching an agreement among themselves, where such an agreement is needed for the correct operation of the system.
  - One example of BFT in use is bitcoin. The bitcoin network works in parallel to generate a blockchain with proof-of-work allowing the system to overcome Byzantine failures and reach a coherent global view of the system's state.

Source: https://en.wikipedia.org/wiki/Byzantine_fault

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Consensus components

- **Blockchain consensus algorithms**
  - Behind every cryptocurrency, there's a consensus algorithm. No consensus algorithm is perfect, but they each have their strengths. In the world of crypto, consensus algorithms exist to prevent double spending.

  - Proof of Work (PoW)
  - Proof of Stake (PoS)
  - Delegated Proof of Stake (DPOS)
  - Proof of Burn (PoB)
  - Practical Byzantine fault tolerant Mechanism (PBFT)
  - …

Source: https://www.newgenapps.com/blog/8-blockchain-consensus-mechanisms-and-benefits

Consensus components

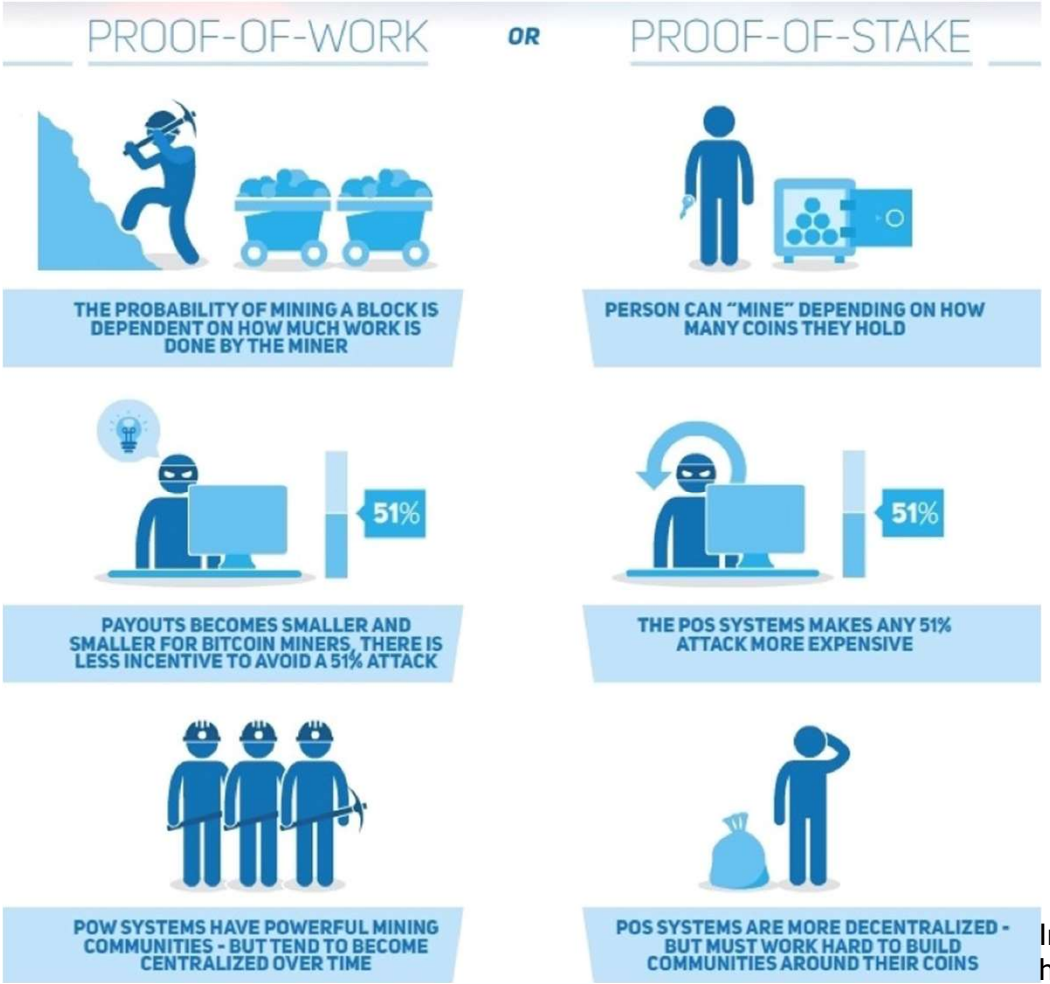

Image source: https://cointelegraph.com/storage/uploads/view/ea5

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Consensus components

- **Blockchain structure**
  - No more client/server architecture with name roles

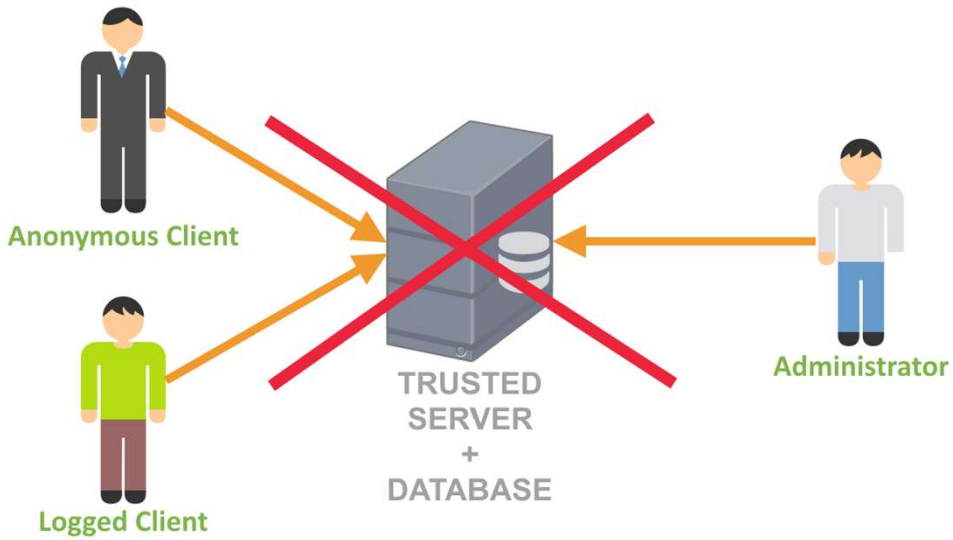

Image source: Scorechain

Consensus components

- **Blockchain structure**
  - Peer-to-peer Architecture with pseudonymous client bearing key pairs. Each node as a database copy.

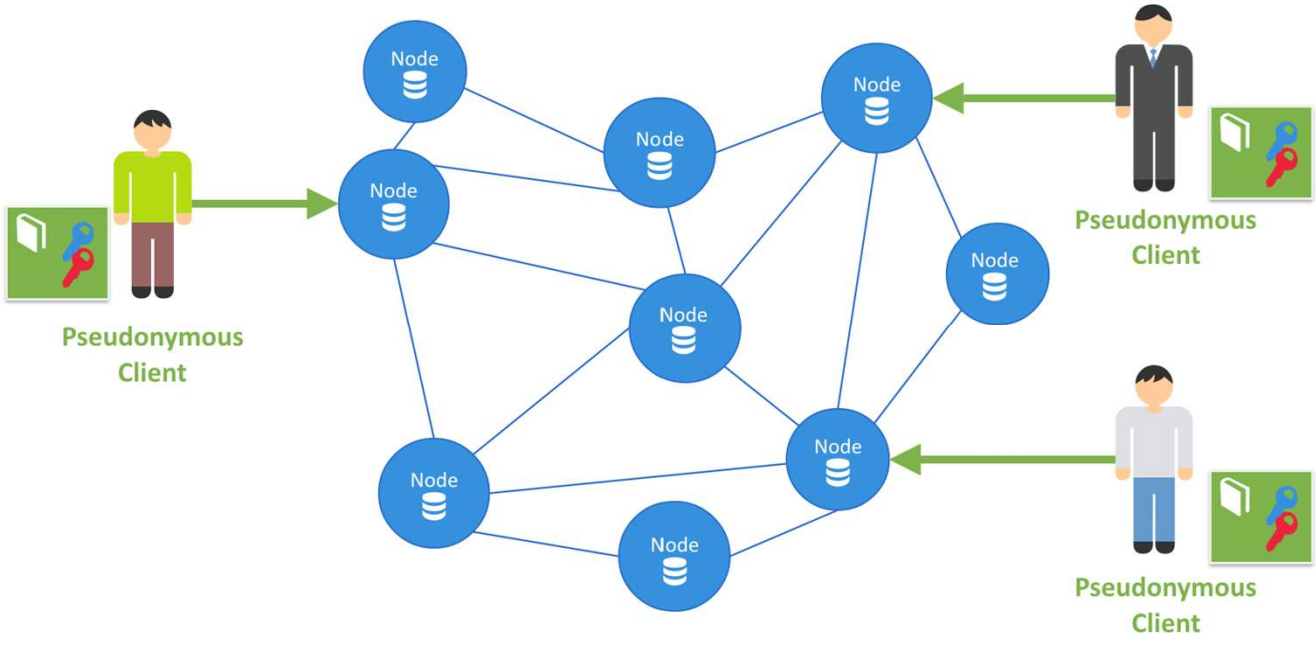

Image source: Scorechain

Consensus components

- **Blockchain structure**
  - Data structure:

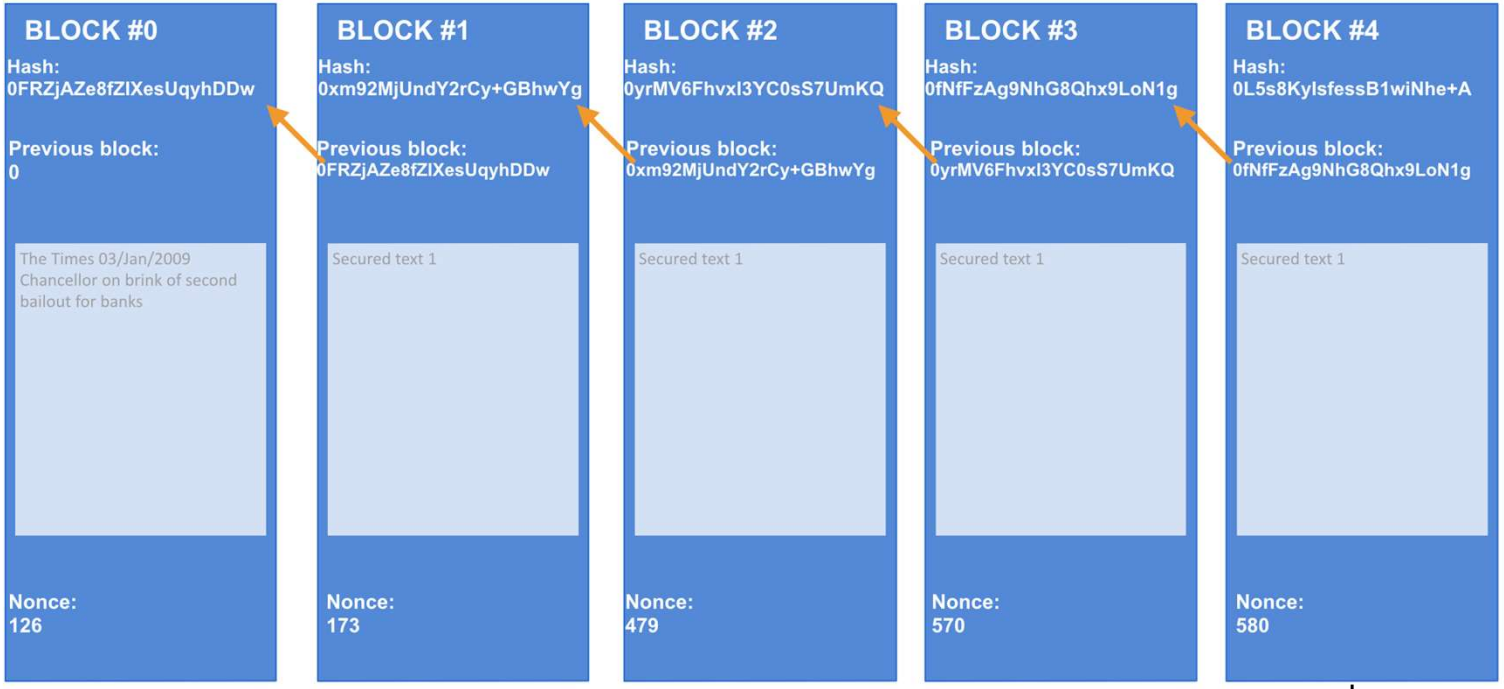

Image source: Scorechain

Consensus components

- **Blockchain structure**
  - Blocks of data:

```
yallet@tyler:~/.bitcoin/blocks$ find . -name 'blk*.dat' -mtime -7 -ls
26610095 130688 -rw-------   1 yallet   yallet   133819048 Nov 23 20:37 ./blk00688.dat
26610563 130556 -rw-------   1 yallet   yallet   133682935 Nov 25 16:30 ./blk00690.dat
26611820 130992 -rw-------   1 yallet   yallet   134128511 Nov 24 17:53 ./blk00689.dat
26609041 131076 -rw-------   1 yallet   yallet   134217422 Nov 22 21:51 ./blk00687.dat
26610902 130840 -rw-------   1 yallet   yallet   133975212 Nov 21 20:41 ./blk00686.dat
26612258 130460 -rw-------   1 yallet   yallet   133583976 Nov 26 13:46 ./blk00691.dat
26611825 114692 -rw-------   1 yallet   yallet   117440512 Nov 28 09:34 ./blk00693.dat
26611491 130112 -rw-------   1 yallet   yallet   133230159 Nov 27 14:49 ./blk00692.dat
yallet@tyler:~/.bitcoin/blocks$ hexdump -C blk00691.dat | head -n 15
00000000  f9 be b4 d9 53 3a 0f 00  00 00 00 20 f3 48 e2 80  |....S:..... .H..|
00000010  bb 89 03 22 dd e9 93 ad  9e bc fd 7e 53 14 45 7a  |..."-------~S.Ez|
00000020  b5 f2 97 00 00 00 00 00  00 00 00 00 1f 5b e2 c0  |-------------[..|
00000030  d1 7d cb 96 9a 37 86 21  c4 a8 af 5a ad a0 ad 0b  |.}...7.!...Z....|
00000040  b2 d2 ef 15 75 c3 3a c6  67 6e 46 0e de 58 38 58  |....u.:.gnF..X8X|
00000050  d4 e6 03 18 3e c5 4e e3  fd 45 0b 01 00 00 00 01  |....>.N..E......|
00000060  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00  |----------------|
*
00000080  ff ff ff ff 49 03 d0 b8  06 2f 48 61 6f 42 54 43  |....I..../HaoBTC|
00000090  2f e7 94 bb e5 9b be e7  9c 81 e8 af 86 e6 98 a5  |/---------------|
000000a0  e9 a3 8e e9 9d a2 ef bc  8c e7 8e af e4 bd a9 e7  |----------------|
000000b0  a9 ba e5 bd 92 e6 9c 88  e5 a4 9c e9 ad 82 e3 80  |----------------|
000000c0  82 2f 06 74 7d 3d e3 b3  1d 9c f7 99 01 00 ff ff  |./.t}=----------|
000000d0  ff ff 01 4b 1d d3 4e 00  00 00 00 19 76 a9 14 bf  |...K..N.....v...|
000000e0  d3 eb b5 48 5b 49 a6 cf  16 57 82 46 23 ea d6 93  |...H[I...W.F#...|
yallet@tyler:~/.bitcoin/blocks$
```

Image source: Scorechain

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Consensus components

- **Types of blockchain**
  - There mainly three types of Blockchains that have emerged after Bitcoin introduced Blockchain to the world.
  - ✓ Public Blockchain:

no one in charge, anyone can participate in reading/writing/auditing the blockchain (i.e. Bitcoin, Litecoin, etc.)

  - ✓ Private Blockchain:

a private property of an individual or an organization, there is one in charge of important things such as read/write or whom to selectively give access to read or vice versa (i.e. Bankchain)

  - ✓ Consortium or Federated Blockchain:

More than one in charge. A group of companies or representative individuals come together and make decisions for the best benefit of the whole network (i.e. r3, EWF)

Soucre: https://coinsutra.com/different-types-blockchains

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Smart Contract Theory and architecture

- **Smart Contract Theory**
  - A computer protocol designed digitally facilitate, verify, or enforce the negotiation or performance of a contract.
  - It allows the performance of credible transactions without the third parties.
  - The transactions are traceable and irreversible.

Source: https://en.wikipedia.org/wiki/Smart_contract

Smart Contract Theory and architecture

- **Smart Contract architecture**

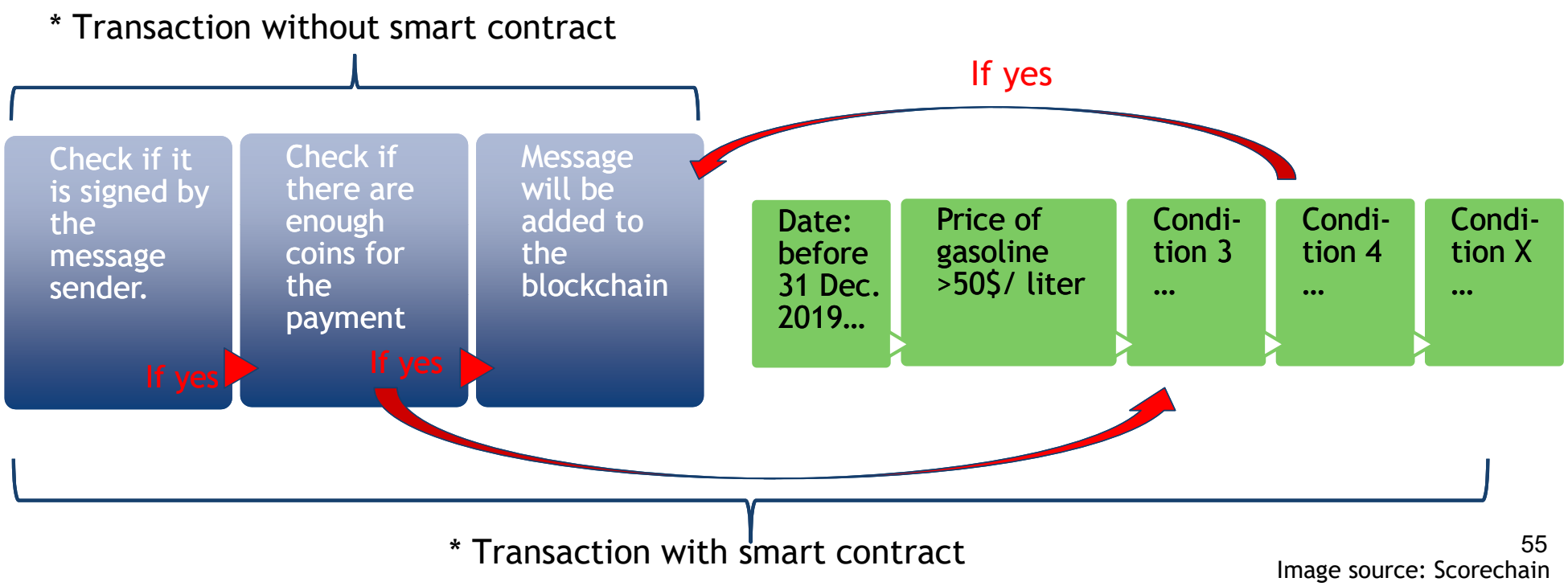

Image source: Scorechain

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Architectures and decentralized autonomous systems

- **DAO (**Decentralized Autonomous Organization**)**
  - An organization represented by rules encoded as a computer program, which is transparent, controlled by shareholders and not influenced by a central government.
  - It's notionally like the example for getting funds for a small conference, except that it includes much more. Members buy shares in the DAO and can vote on things according to the number of shares they have. The dreamers have the idea they'll replace Democracy and run entire countries this way.
  - The DAO was the largest crowdfunding in history, having raised over $150m from more than 11,000 enthusiastic members. (ICO)
  - A DAO's financial transaction record and program rules are maintained on a blockchain.

Source:
https://blog.erratasec.com/2016/06/etheriumdao-hack-similfied.html#.XHbF3VNKhPN
https://medium.com/@nasirhm/understanding-the-dao-attack-9328a230243

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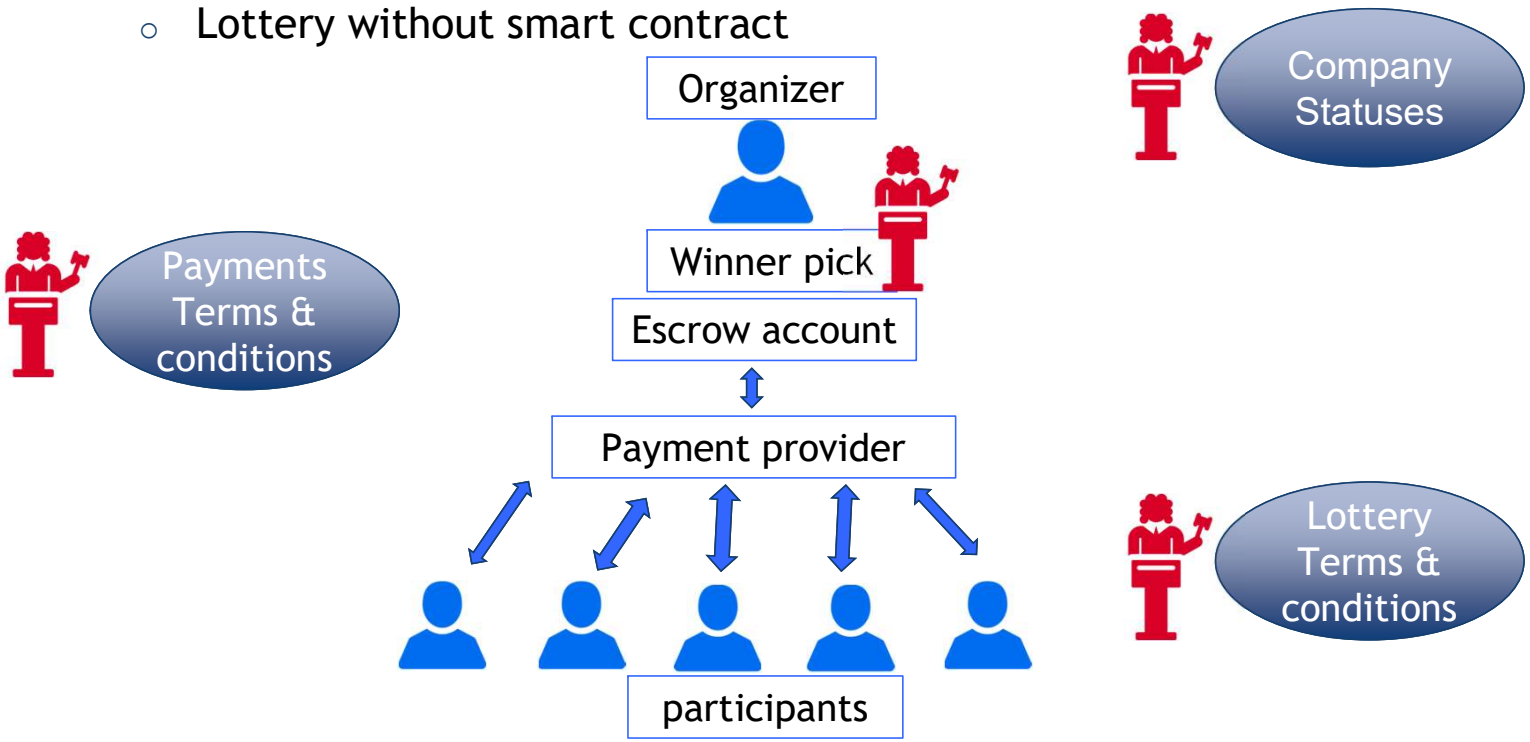
Smart contract application

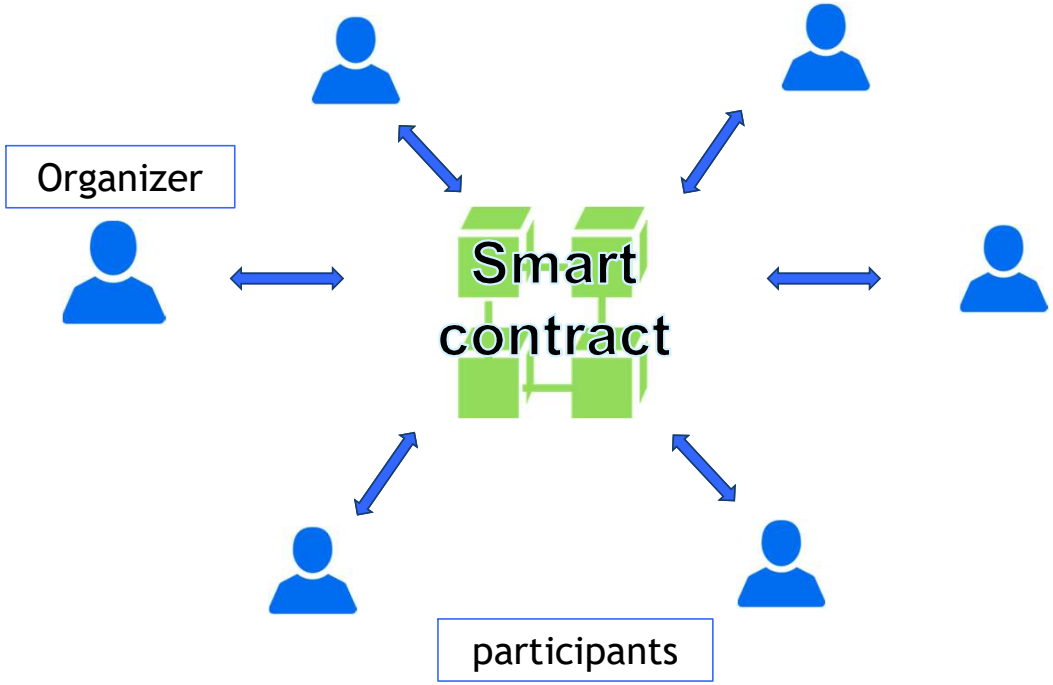
- **Example 1: Lottery**
  - Lottery without smart contract



Source: https://www.slideshare.net/ThomasCharlesVanderstraeten/ethereum-smart-contract-101-with-cryptizensio

Smart contract application

- **Example 1: Lottery**
  - Lottery with smart contract

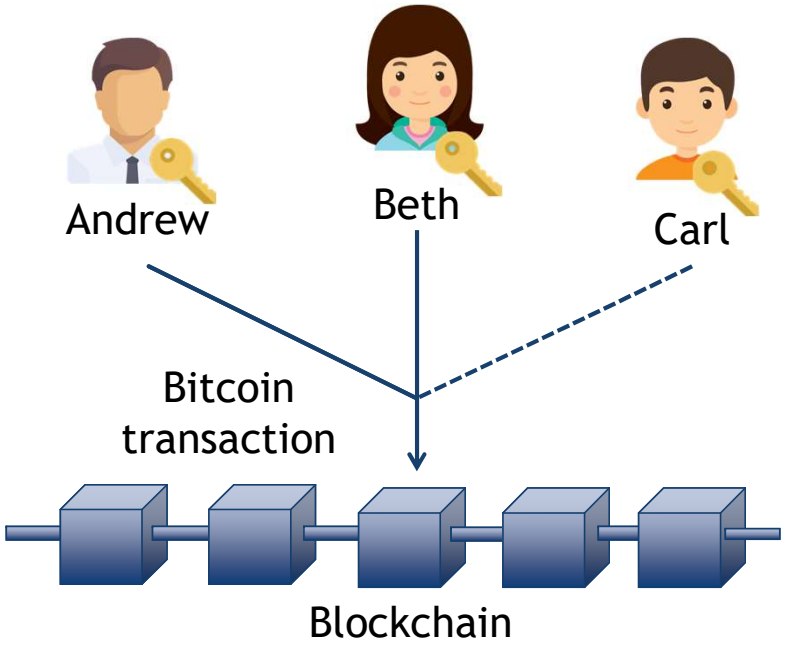


Source: https://www.slideshare.net/ThomasCharlesVanderstraeten/ethereum-smart-contract-101-with-cryptizensio

Smart contract application

- **Example 2-1: Group wallets**
  - Enforcing at least 2 out of 3 people of a group to agree to create a valid transaction

```
2 <pubKeyAndrew>
<pubKeyBeth>
<pubKeyCarl> 3
CHECKMULTISIG
```

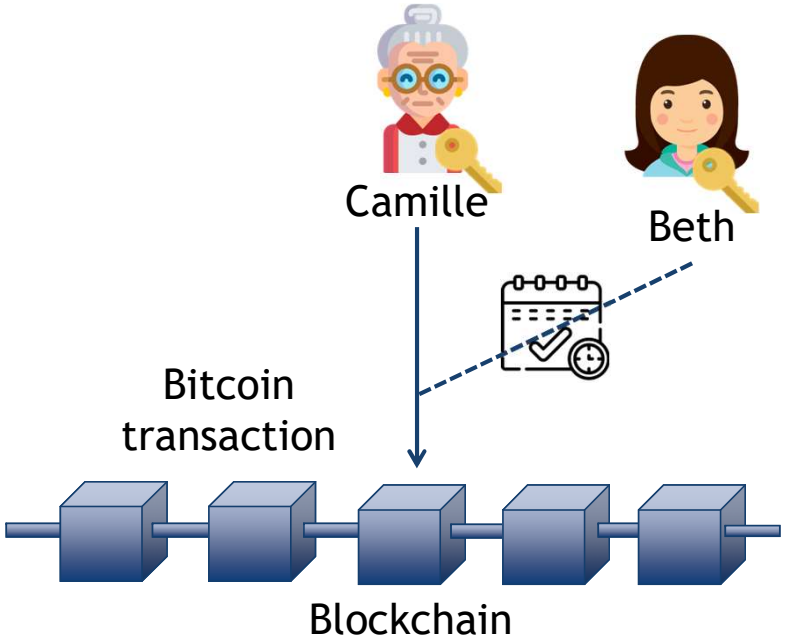


Source: https://www.slideshare.net/FedericoTenga/state-smart-contract-ttechnologies

Smart contract application

- **Example 2-2: Heritage wallets**
  - Enforcing that a transaction must be signed either by Camille OR by Beth after 5 years

```
IF
   <pubKeyCamille>
   CHECKSIG
ELSE
   <5 y> CLTV DROP
   <pubKeyBeth>
    CHECKSIG
ENDIF
```

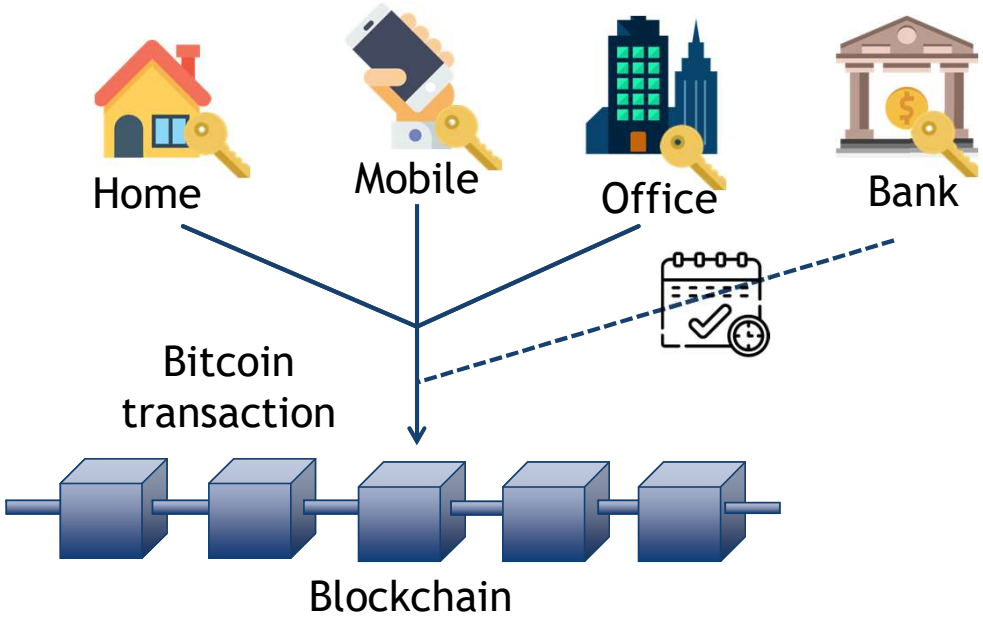


Source: https://www.slideshare.net/FedericoTenga/state-smart-contract-ttechnologies

Smart contract application

- **Example 2-3: Secure storage**
  - Enforcing that a transaction must be signed by either 3 devices in different locations OR a recovery key deposited in the bank after 8 months

```
IF
      3 <pubKeyHome>
       <pubKeyMobile>
      <pubKeyOffice> OP_3
       CHECKMULTISIG
ELSE
      <8 m> CLTV DROP
      <pubKeyBank>
      CHECKSIG
ENDIF
```



Source: https://www.slideshare.net/FedericoTenga/state-smart-contract-ttechnologies

Existing blockchain applications, related structures and architectures

- **ERC-20**
  - Proposed on November 19, 2015 by Fabian Vogelsteller.
  - A technical standard used for smart contracts on the Ethereum blockchain for implementing tokens. (ERC: Ethereum Request for Comment, 20: the number that was assigned to this request.)
  - It defines a common list of rules that an Ethereum token has to implement, allowing developers to program how new tokens will function within the Ethereum ecosystem. These rules include how the tokens are transferred between addresses and how data within each token is accessed.
  - + 142,200 ERC-20 token contracts (as of November 19, 2018): EOS, Bancor, Qash, etc…

Source: https://en.wikipedia.org/wiki/ERC-20

Existing blockchain applications, related structures and architectures

- **ERC-721: a class of unique tokens**
  - A free, open standard that describes how to build non-fungible or unique tokens on the Ethereum blockchain. While most tokens are fungible (every token is the same as every other token, i.e.ERC-20), ERC-721 tokens are all unique.
  - It defines a minimum interface a smart contract must implement to allow unique tokens to be managed, owned and traded.
- **ERC-725: Ethereum Identity Standard**
  - A proposed standard for blockchain-based identity which lives on the Ethereum blockchain.
  - It describes proxy smart contracts that can be controlled by multiple keys and other smart contracts, it can describe humans, groups, objects and machines.
  - Users should be able to own and manage their identity instead of ceding ownership of identity to centralized organizations.

Source:
http://erc721.org/
https://erc725alliance.org/