Digital Currencies

Transforming the Future of Money
WAAS & Future Capital Initiative
Dubrovnik, November 18-20, 2019

Georgios THEODOROPOULOS

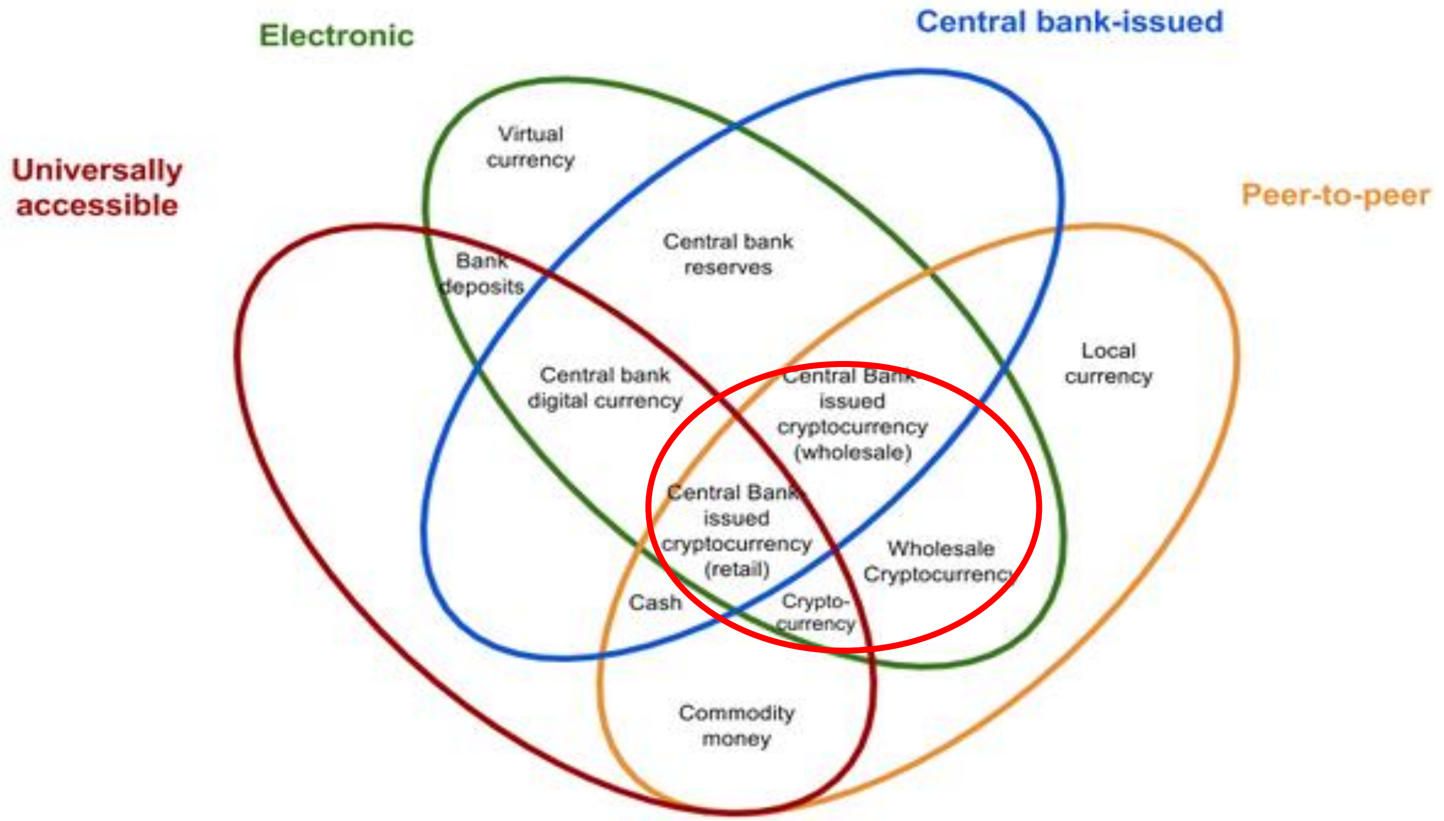
Chair Professor

Dept. of Computer Science and Engineering

SUSTech, Shenzhen, China

Money

The money flower: a taxonomy of money



Adaptation from Bank for International Settlements (2017)

Cryptocurrencies are virtual currencies， **digital representations of value**, not issued by a central bank, credit institution or e-money institution, which in some circumstances can be used as an **alternative to money**. **Unregulated, digital money, which is issued and usually controlled by its developers**, and used and accepted among the members of a **specific virtual community**

Cryptocurrencies are a subset of virtual currencies which are **digital representations of value**, **issued by private developers** and **denominated in their own unit of account**.

Cryptocurrencies are **digital currencies** with following features:

- they are assets, the value of which is determined by supply and demand, similar in concept to commodities such as gold, yet with zero intrinsic value;
- **make use of distributed ledgers** to allow remote peer-to-peer exchanges of electronic value in the absence of trust between parties and **without the need for intermediaries**
- they are **not operated by any specific individual or institution**

EBA European Banking Authority

Cryptocurrencies are **virtual currencies, digital representations of value** that are neither issued by a central bank or public authority nor **necessarily attached to a fiat currency** but are used by natural or legal persons as a means of exchange and can be transferred, stored or traded electronically

esma European Securities and Markets Authority

Adopts EBA definition

WORLD BANK

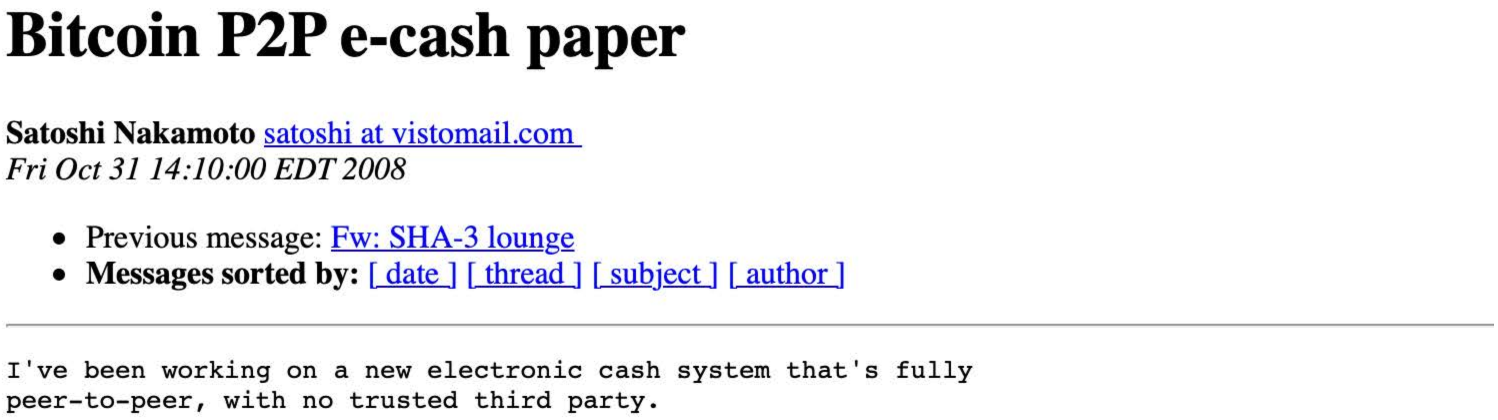
Cryptocurrencies are a subset of digital currencies, **digital representations of value that are denominated in their own unit of account**, **distinct from e-money**, which is simply a digital payment mechanism, representing and denominated in fiat money.

FATF Financial Action Task Force

Cryptocurrencies are **math-based, decentralized, convertible virtual currencies** that are protected by cryptography

Blockchain

- It all started with a 2008 white paper sent by Satoshi Nakamoto to the Cryptography Mailing List.



Bitcoin P2P e-cash paper

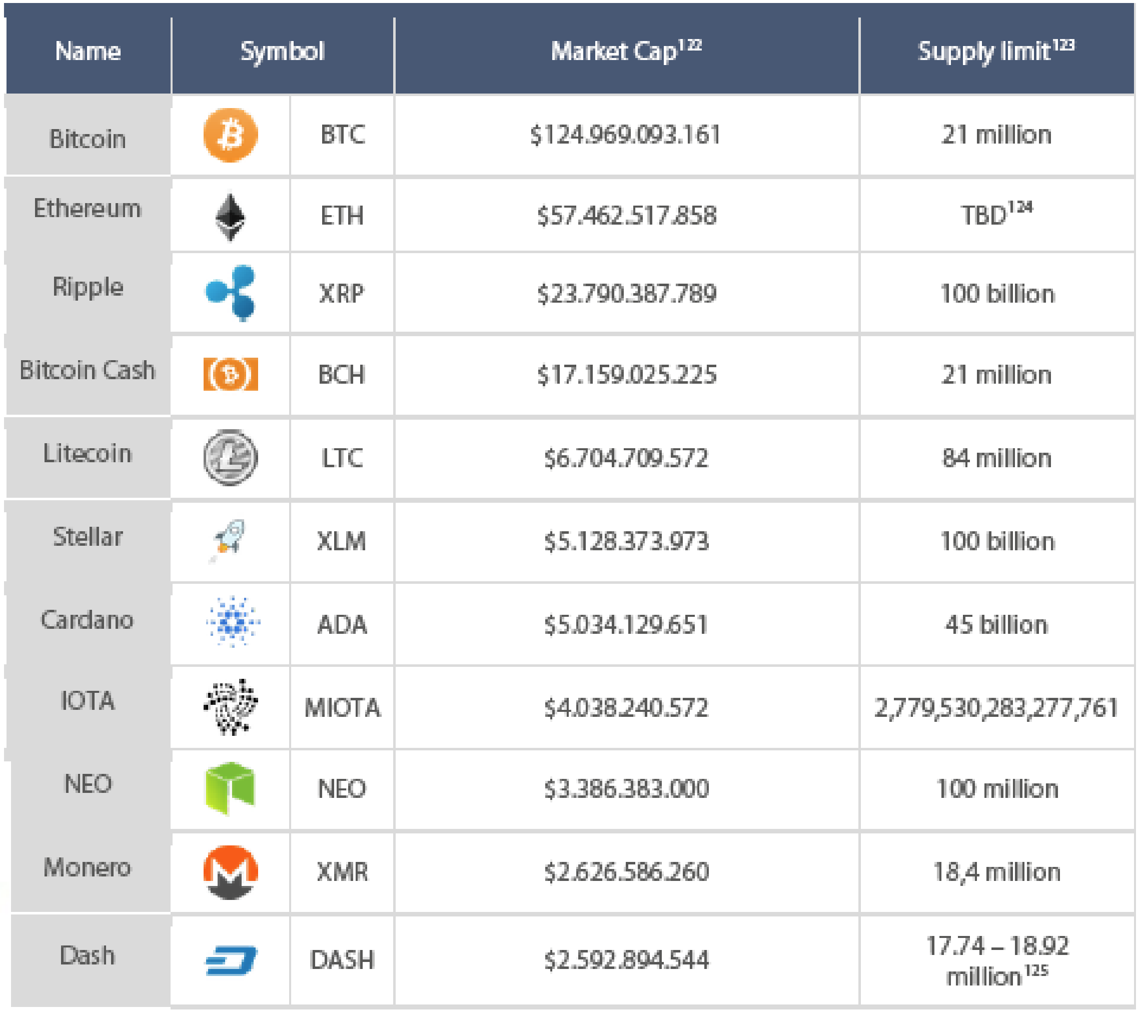
Satoshi Nakamoto satoshi at vistomail.com
Fri Oct 31 14:10:00 EDT 2008

- Previous message: Fw: SHA-3 lounge
- **Messages sorted by:** [date] [thread] [subject] [author]

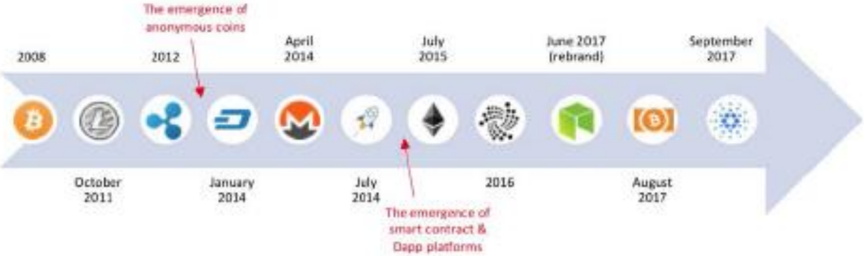
```
I've been working on a new electronic cash system that's fully
peer-to-peer, with no trusted third party.
```

> *"We proposed a peer-to-peer network using proof-of-work to record a public history of transactions that* ***quickly becomes computationally impractical*** *for an attacker to change if honest nodes control a majority of CPU power"*

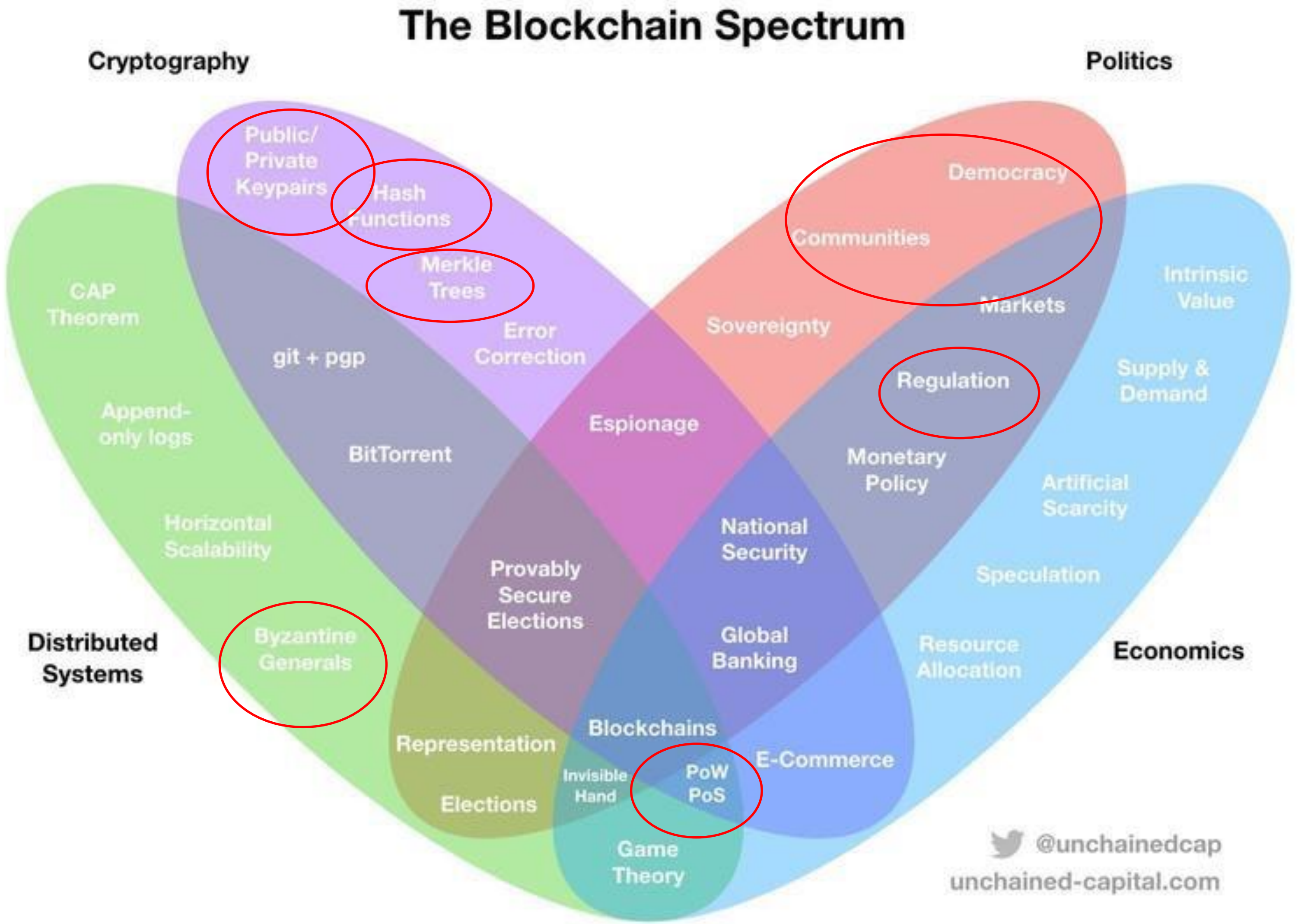
- Bitcoin vs Altcoins : not based on Bitcoin’s open-source protocol
- There are approximately 2,950 cryptocurrencies being traded with a total market capitalisation of $221bn (as of October 8th 2019).
- The top 10 cryptocurrencies represent roughly 85% of the total market value



Name	Symbol	Market Cap[122]	Supply limit[123]
Bitcoin	BTC	$124.969.093.161	21 million
Ethereum	ETH	$57.462.517.858	TBD[124]
Ripple	XRP	$23.790.387.789	100 billion
Bitcoin Cash	BCH	$17.159.025.225	21 million
Litecoin	LTC	$6.704.709.572	84 million
Stellar	XLM	$5.128.373.973	100 billion
Cardano	ADA	$5.034.129.651	45 billion
IOTA	MIOTA	$4.038.240.572	2,779,530,283,277,761
NEO	NEO	$3.386.383.000	100 million
Monero	XMR	$2.626.586.260	18,4 million
Dash	DASH	$2.592.894.544	17.74 – 18.92 million[125]



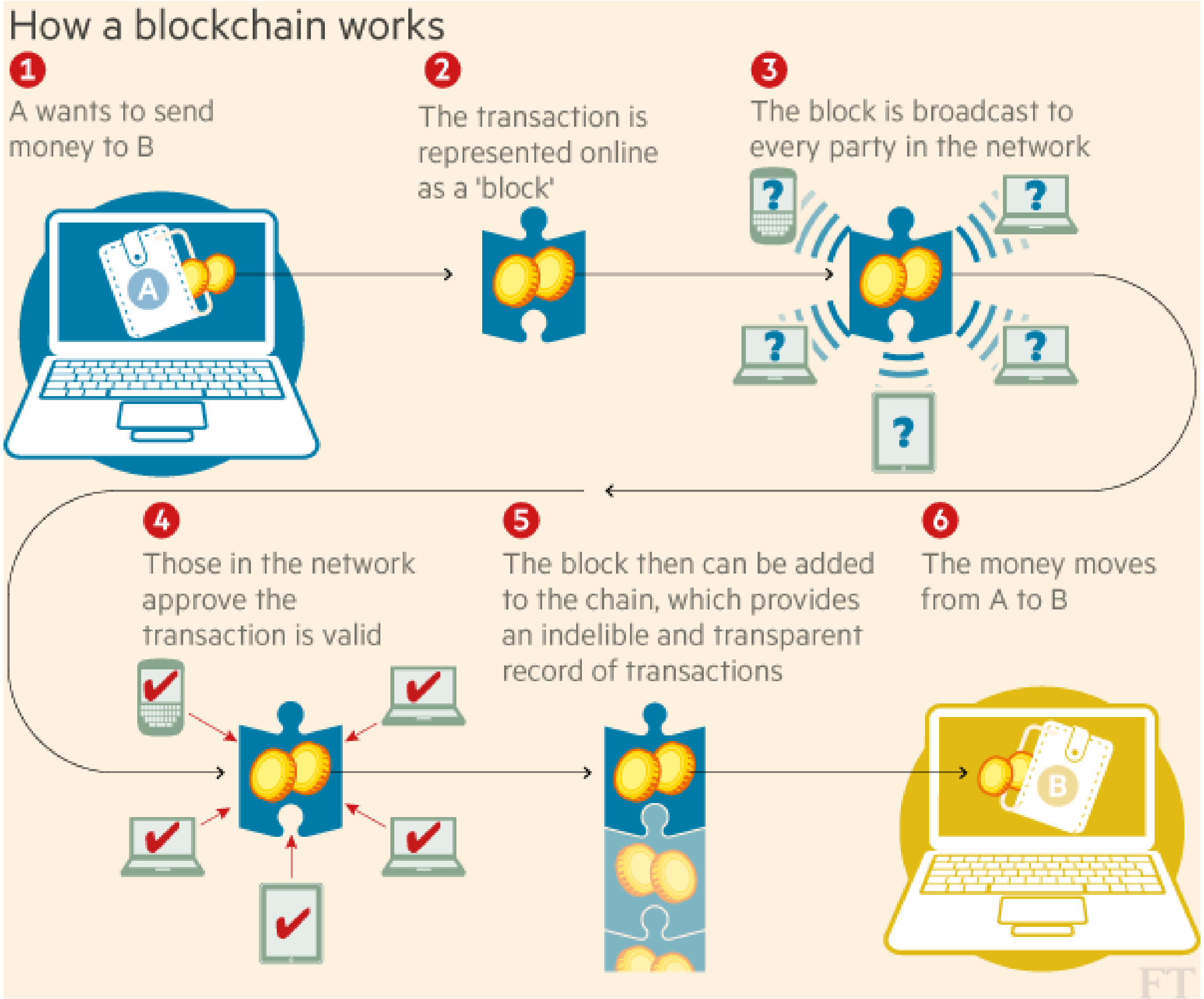
Source: *Cryptocurrencies and blockchain, Policy Department for Economic, Scientific and Quality of Life Policies, Directorate-General for Internal Policies, PE 619.024 - July 2018*


The Blockchain Spectrum
Cryptography
Politics
Distributed Systems
Economics
Public/ Private Keypairs
Hash Functions
Merkle Trees
Error Correction
CAP Theorem
git + pgp
Append-only logs
BitTorrent
Horizontal Scalability
Byzantine Generals
Democracy
Communities
Markets
Sovereignty
Regulation
Intrinsic Value
Supply & Demand
Monetary Policy
Artificial Scarcity
Speculation
Resource Allocation
Espionage
National Security
Provably Secure Elections
Global Banking
Blockchains
Representation
Elections
Invisible Hand
PoW PoS
E-Commerce
Game Theory
@unchainedcap
unchained-capital.com

Blockchain Keywords

- **ledger** – the abstraction at the heart of blockchain systems: a log of **transactions** that take place between various parties; establishes which transactions happened and in which order. Ledgers are public accessible but tamper-proof.
- **Decentralised, distributed** – divided among many, in multiple locations;
- **mutual** – shared in common, or owned by a community;
- **mutual distributed ledger** (MDL) – a record of transactions shared in common and stored in multiple locations;
- **mutual distributed ledger technology** – a technology that provides an immutable record of transactions shared in common and stored in multiple locations
- **Token:** a unit of value issued by a private organization within blockchain system.
- **Public and Private Keys**
- **Cryptographic hash functions**
- **Consensus protocols (governance)**: Proof of Work, Proof of Stake, etc

Blockchain: How it works



How a blockchain works

1 A wants to send money to B

2 The transaction is represented online as a 'block'

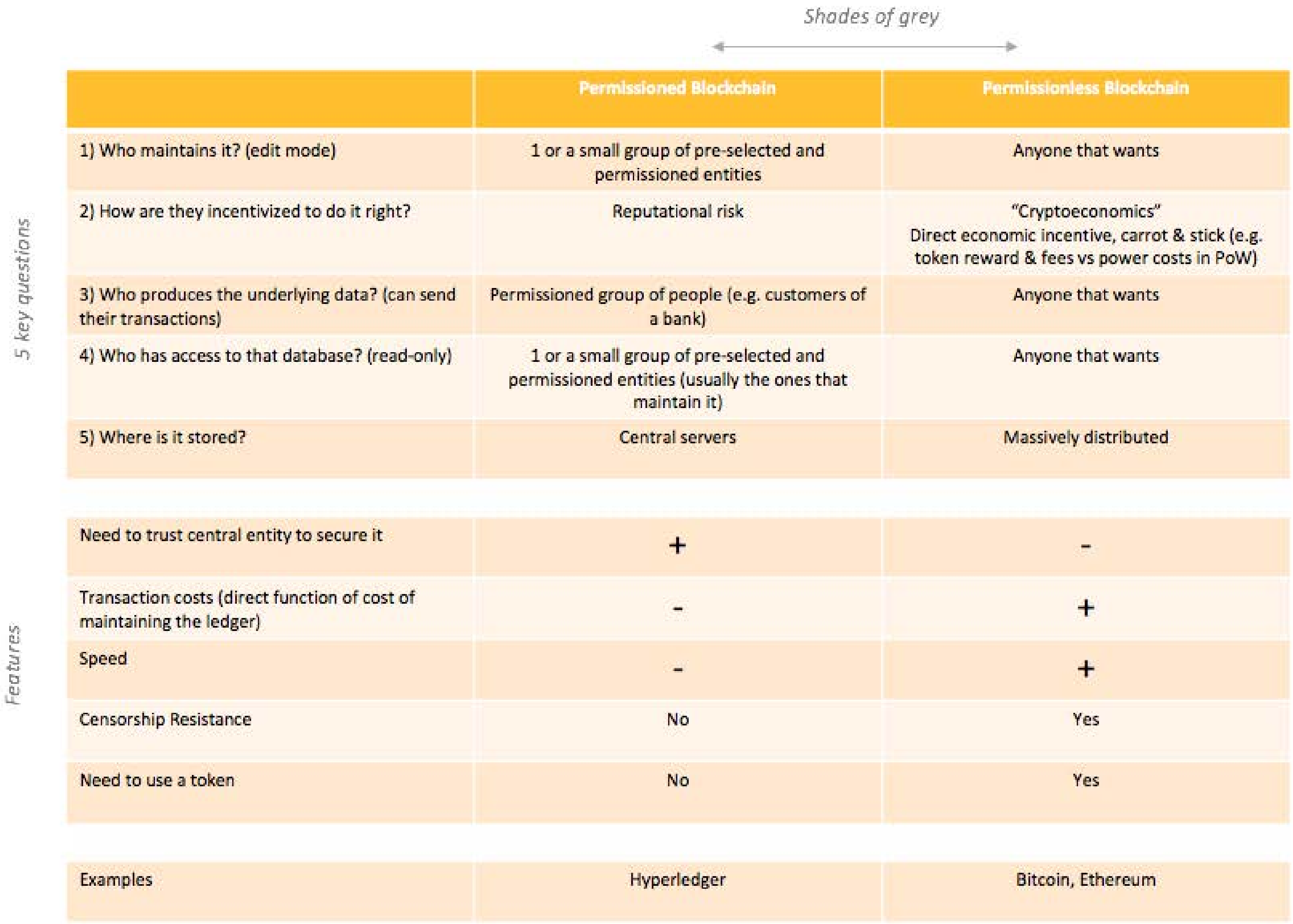
3 The block is broadcast to every party in the network

4 Those in the network approve the transaction is valid

5 The block then can be added to the chain, which provides an indelible and transparent record of transactions

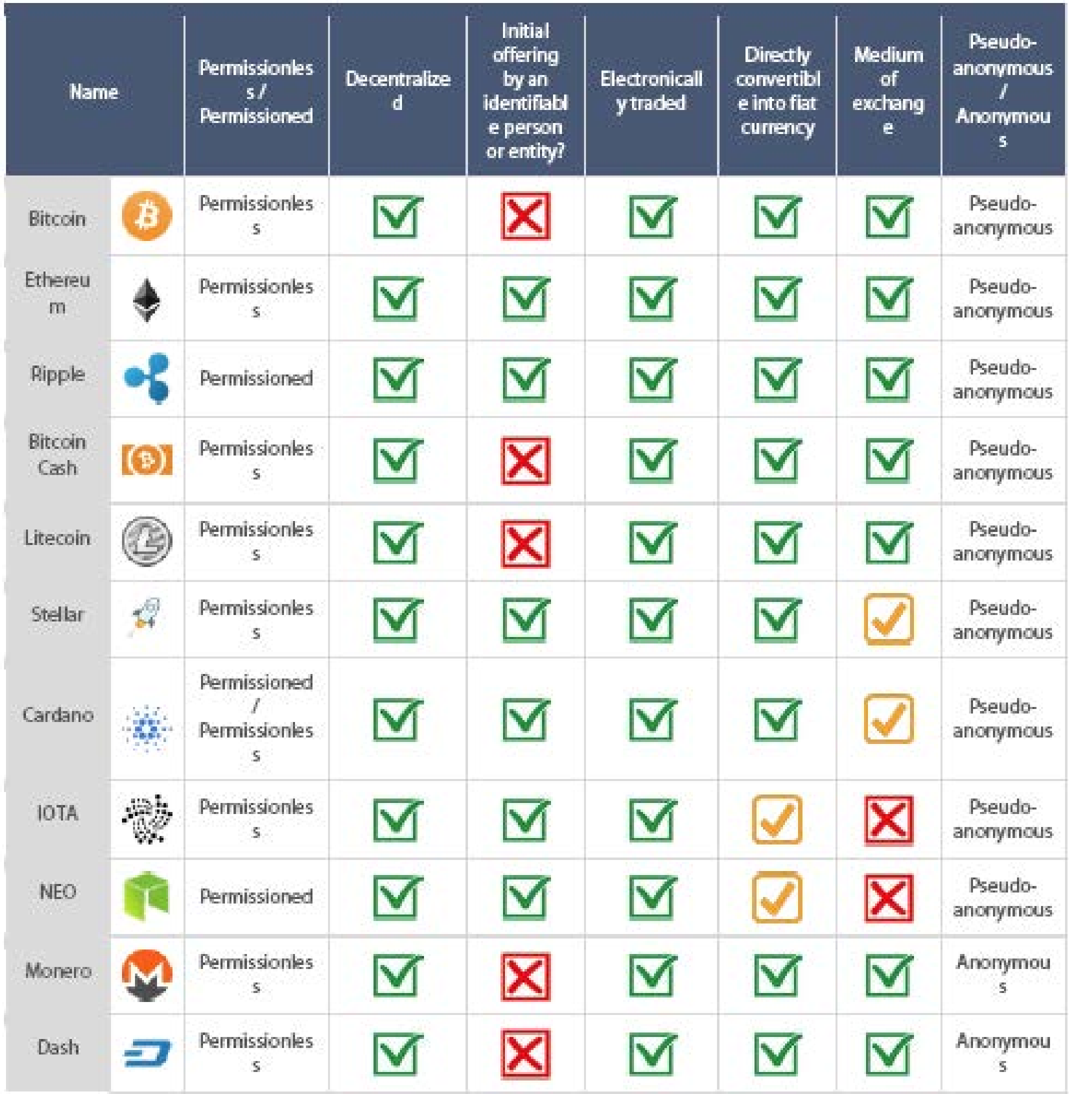
6 The money moves from A to B

Source: *"Technology: Banks seeks the key to blockchain", by J. Wild, M. Arnold and P. Stafford, 1 November 2015, Financial Times*



Shades of grey

		Permissioned Blockchain	Permissionless Blockchain
5 key questions	1) Who maintains it? (edit mode)	1 or a small group of pre-selected and permissioned entities	Anyone that wants
	2) How are they incentivized to do it right?	Reputational risk	"Cryptoeconomics" Direct economic incentive, carrot & stick (e.g. token reward & fees vs power costs in PoW)
	3) Who produces the underlying data? (can send their transactions)	Permissioned group of people (e.g. customers of a bank)	Anyone that wants
	4) Who has access to that database? (read-only)	1 or a small group of pre-selected and permissioned entities (usually the ones that maintain it)	Anyone that wants
	5) Where is it stored?	Central servers	Massively distributed
Features	Need to trust central entity to secure it	+	-
	Transaction costs (direct function of cost of maintaining the ledger)	-	+
	Speed	-	+
	Censorship Resistance	No	Yes
	Need to use a token	No	Yes
	Examples	Hyperledger	Bitcoin, Ethereum

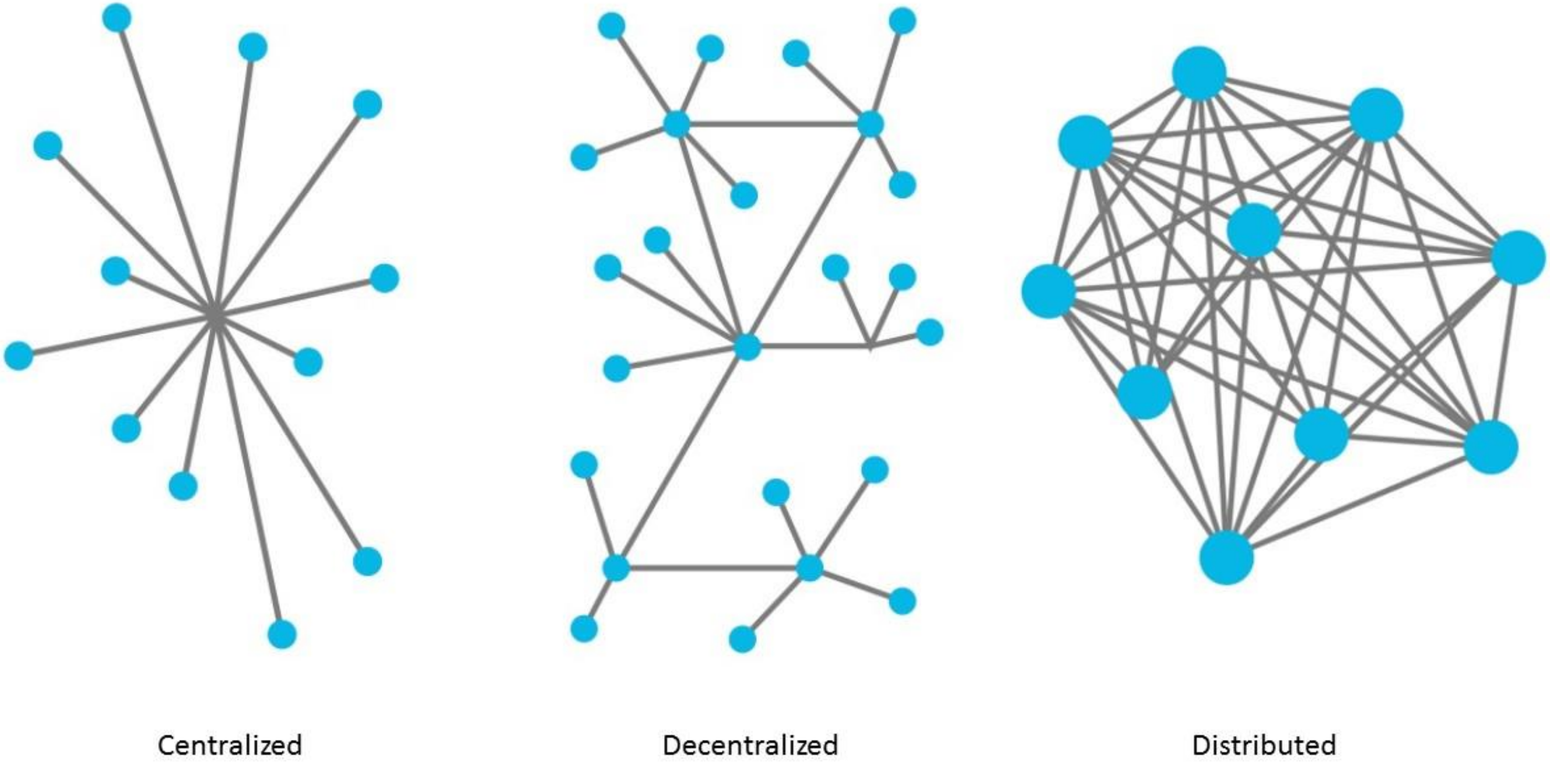


Name	Permissionless / Permissioned	Decentralized	Initial offering by an identifiable person or entity?	Electronically traded	Directly convertible into fiat currency	Medium of exchange	Pseudo-anonymous / Anonymous
Bitcoin	Permissionless	☑	☒	☑	☑	☑	Pseudo-anonymous
Ethereum	Permissionless	☑	☑	☑	☑	☑	Pseudo-anonymous
Ripple	Permissioned	☑	☑	☑	☑	☑	Pseudo-anonymous
Bitcoin Cash	Permissionless	☑	☒	☑	☑	☑	Pseudo-anonymous
Litecoin	Permissionless	☑	☒	☑	☑	☑	Pseudo-anonymous
Stellar	Permissionless	☑	☑	☑	☑	✓	Pseudo-anonymous
Cardano	Permissioned / Permissionless	☑	☑	☑	☑	✓	Pseudo-anonymous
IOTA	Permissionless	☑	☑	☑	✓	☒	Pseudo-anonymous
NEO	Permissioned	☑	☑	☑	✓	☒	Pseudo-anonymous
Monero	Permissionless	☑	☒	☑	☑	☑	Anonymous
Dash	Permissionless	☑	☒	☑	☑	☑	Anonymous

Legend:

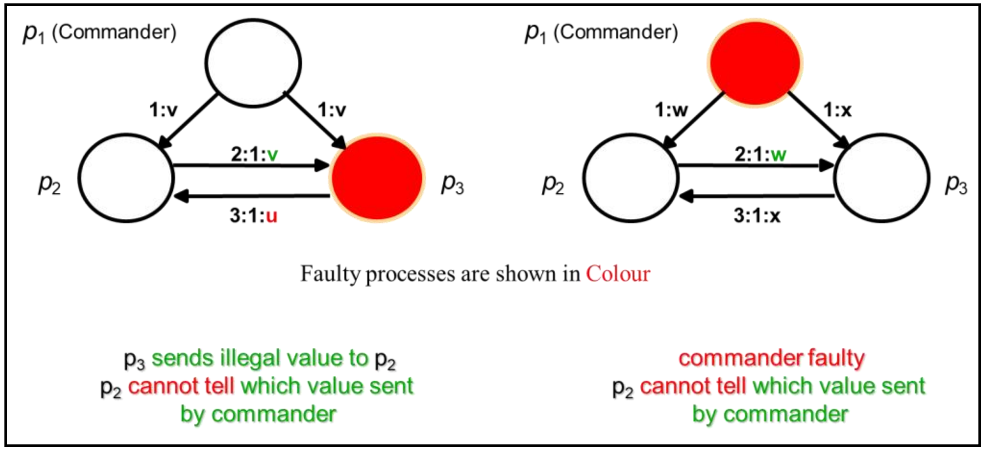
☑	=	Yes
✓	=	To a limited extent
☒	=	No

The Fundamental Challenge: Consensus and Agreement



Consensus and Agreement: The Byzantine Generals Problem

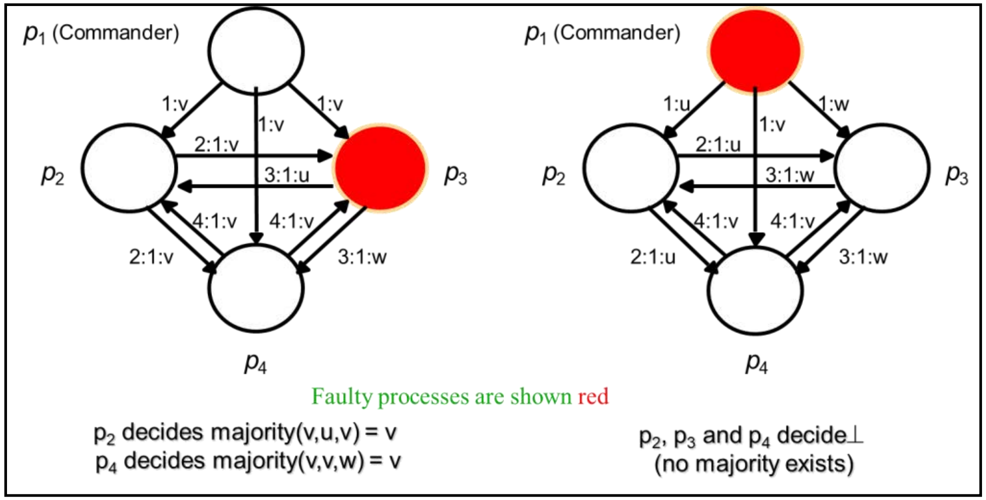
- The systems actors must agree on a concerted strategy, but some of these actors are unreliable.
- The problem [Lamport 1982]
  - three or more (N) generals are to agree to **attack** or **retreat**
  - one (commander) issues the order
  - the others (lieutenants) decide
  - one or more (f) generals are treacherous (or faulty!)
    - propose attacking to one general, and retreating to another
    - either commander or lieutenants can be treacherous!
- In a **synchronous** system: impossibility with $N \leq 3f$
- In **asynchronous** system: impossibility with even one failure!!



Faulty processes are shown in Colour

p_3 sends illegal value to p_2
p_2 cannot tell which value sent by commander

commander faulty
p_2 cannot tell which value sent by commander



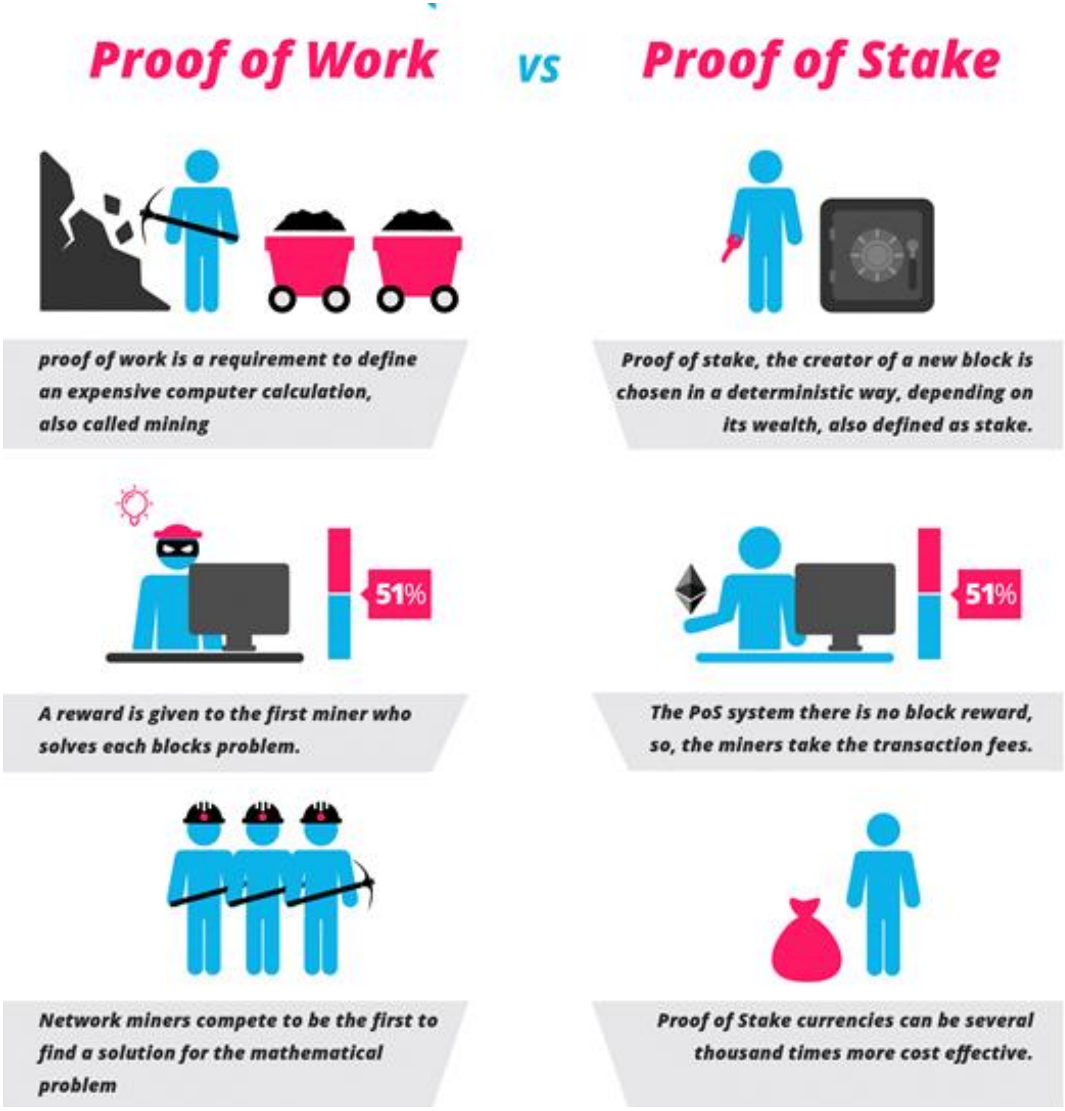
Faulty processes are shown red

p_2 decides majority(v,u,v) = v
p_4 decides majority(v,v,w) = v

p_2, p_3 and p_4 decide $\perp$
(no majority exists)

Consensus protocols in Blockchain

- Blockchains are decentralized ledgers. Each node participating in the blockchain has an independent copy of the ledger.
- To confirm the validity of transactions attempting to be lodged on the ledger, a solution was needed to ensure that 'traitors' could not add their transactions onto the ledger.



proof of work is a requirement to define an expensive computer calculation, also called mining

Proof of stake, the creator of a new block is chosen in a deterministic way, depending on its wealth, also defined as stake.

A reward is given to the first miner who solves each blocks problem.

The PoS system there is no block reward, so, the miners take the transaction fees.

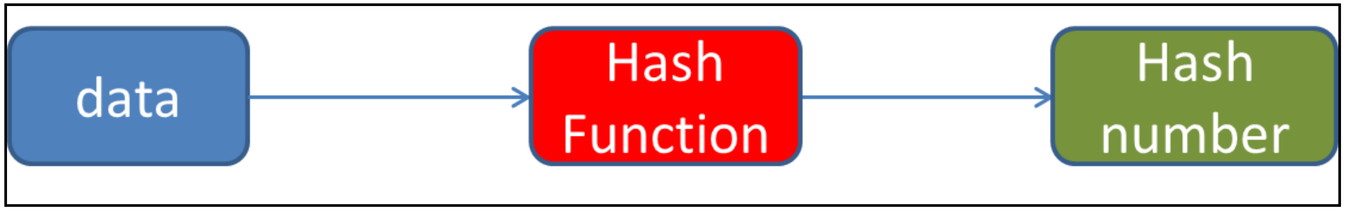
Network miners compete to be the first to find a solution for the mathematical problem

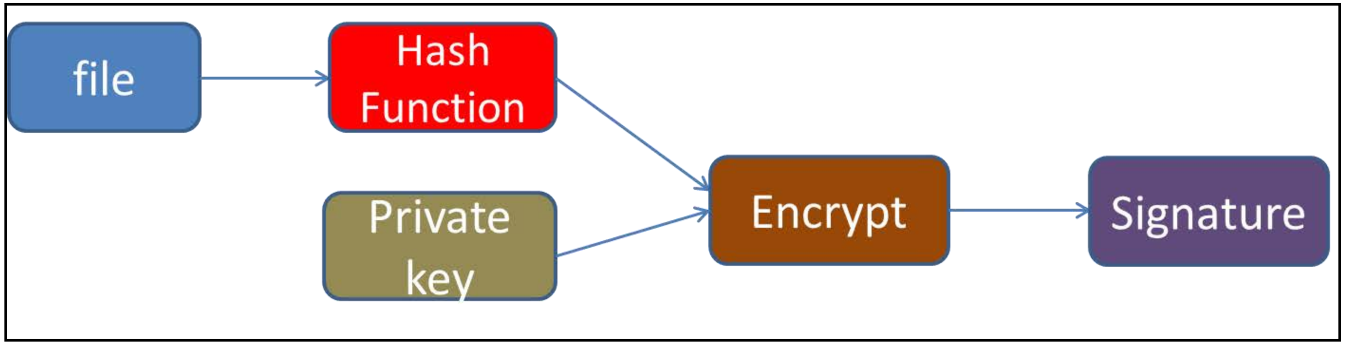
Proof of Stake currencies can be several thousand times more cost effective.

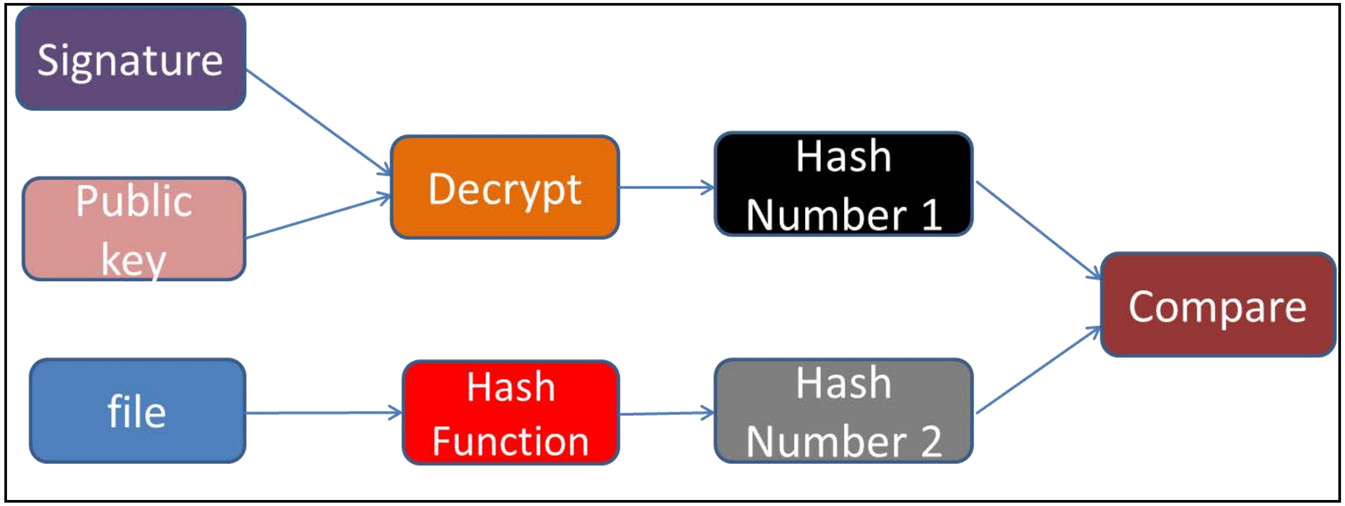
***Source**: blockgeeks.com*

Hashing, Keys and Signatures

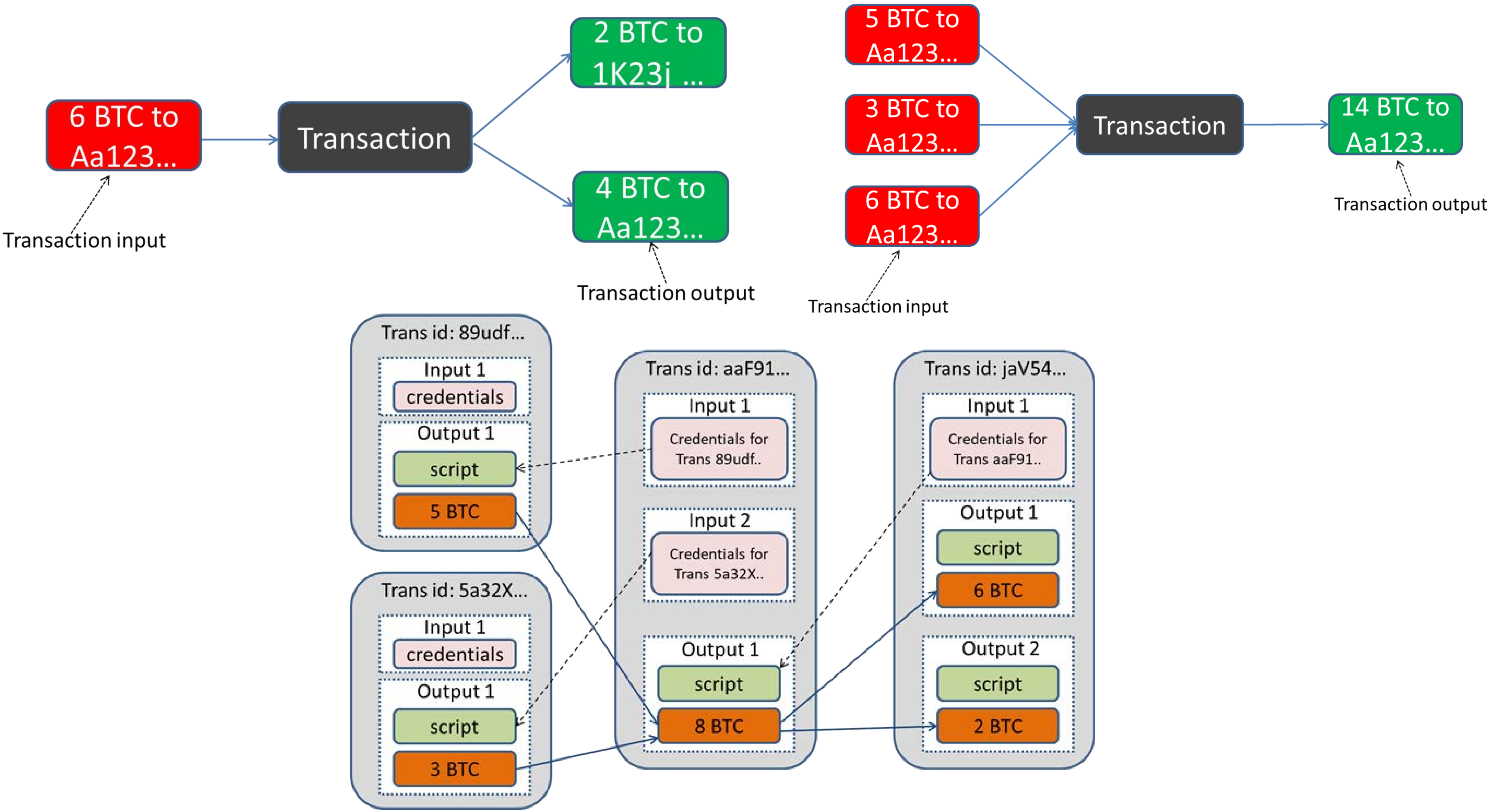
- Hash function is math which takes in data and produces a single number
  - Irreversible
  - Unpredictable
  - Collision probability
- Public Key yields a message only holder can read
- Private Key yields a "digital signature" a message everyone can read but only the holder could have produced



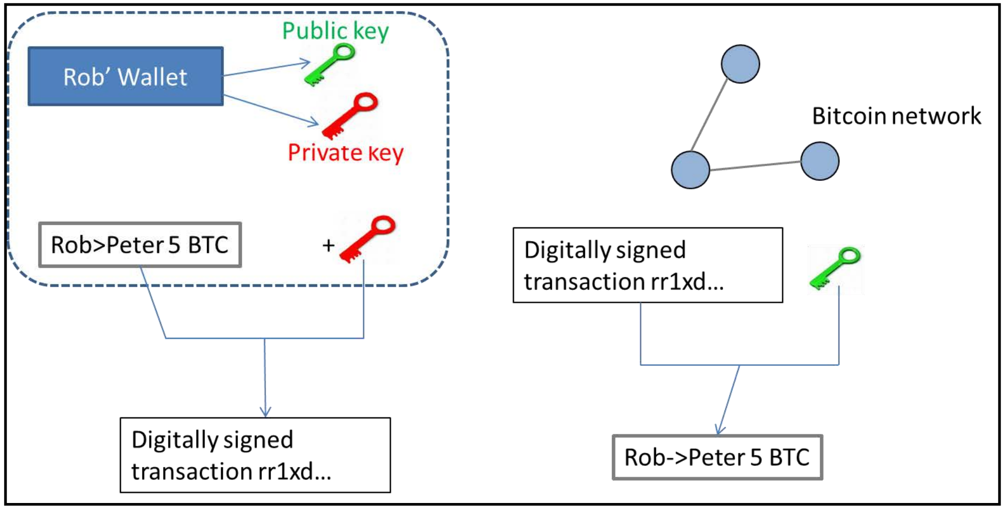




Transactions and Ledgers



Transaction Validation



Public key

Rob' Wallet

Private key

Rob>Peter 5 BTC

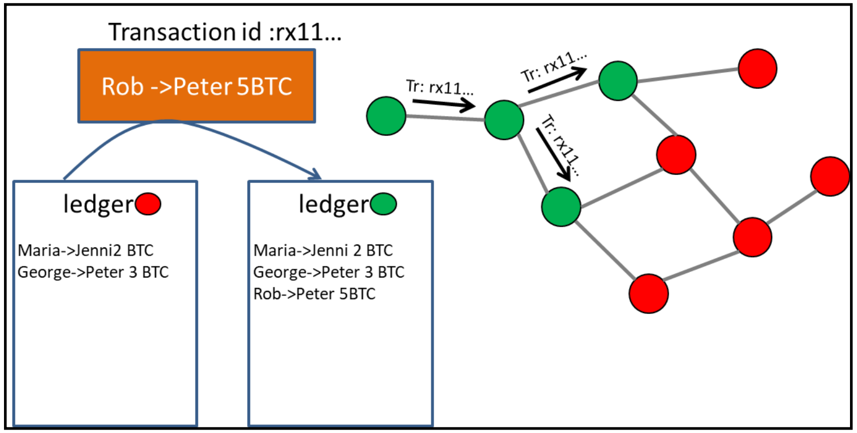
+

Digitally signed transaction rr1xd...

Bitcoin network

Digitally signed transaction rr1xd...

Rob->Peter 5 BTC



Transaction id :rx11...

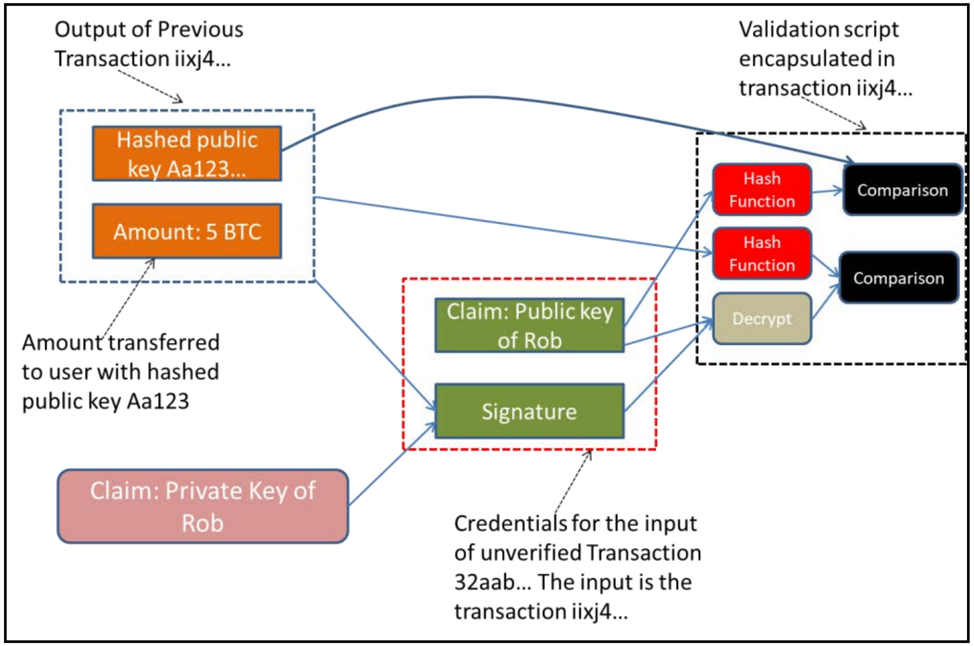
Rob ->Peter 5BTC

ledger

Maria->Jenni2 BTC
George->Peter 3 BTC

ledger

Maria->Jenni 2 BTC
George->Peter 3 BTC
Rob->Peter 5BTC



Output of Previous Transaction iixj4...

Hashed public key Aa123...

Amount: 5 BTC

Amount transferred to user with hashed public key Aa123

Claim: Public key of Rob

Signature

Claim: Private Key of Rob

Credentials for the input of unverified Transaction 32aab... The input is the transaction iixj4...

Validation script encapsulated in transaction iixj4...

Hash Function

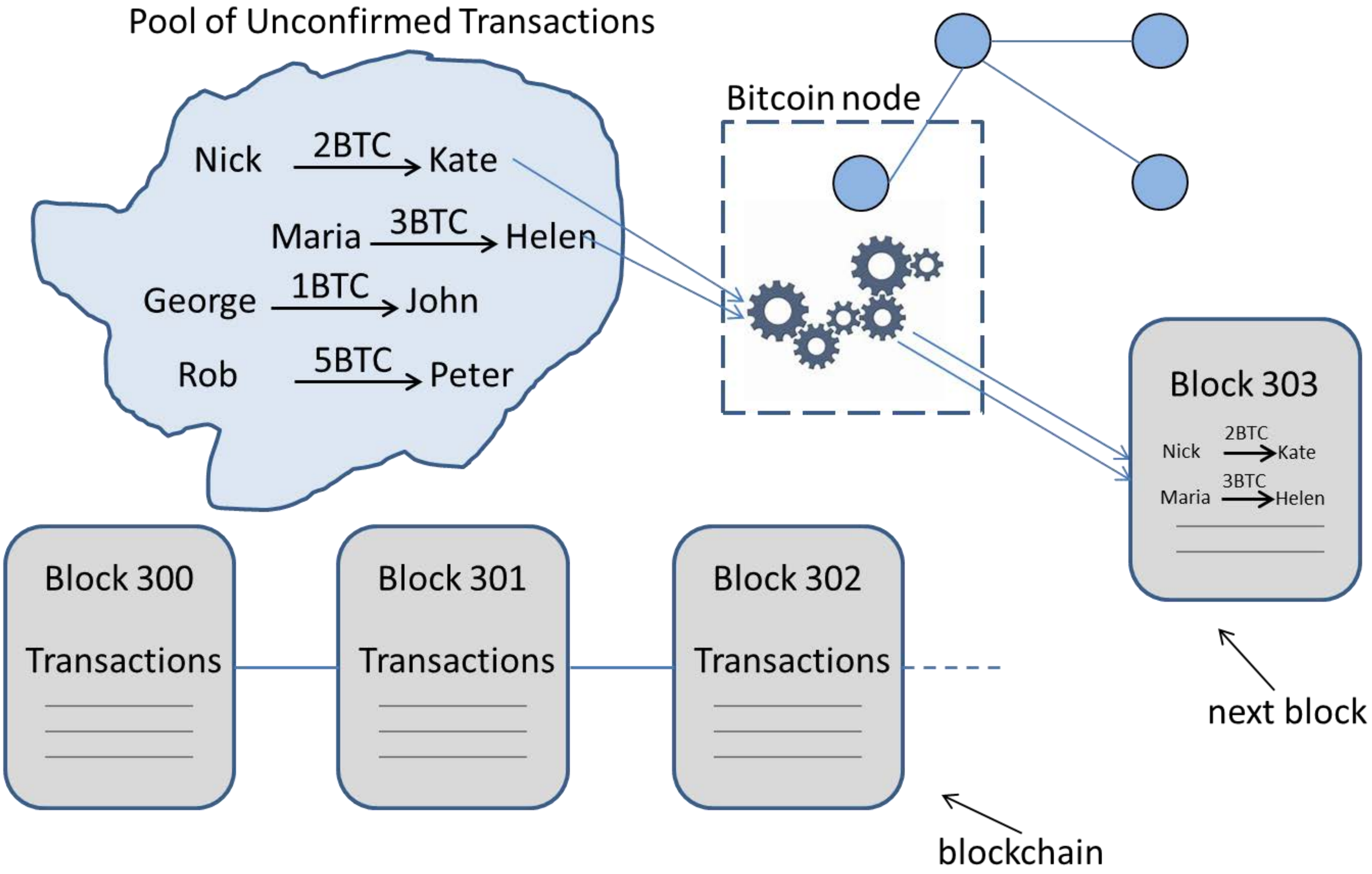
Comparison

Hash Function

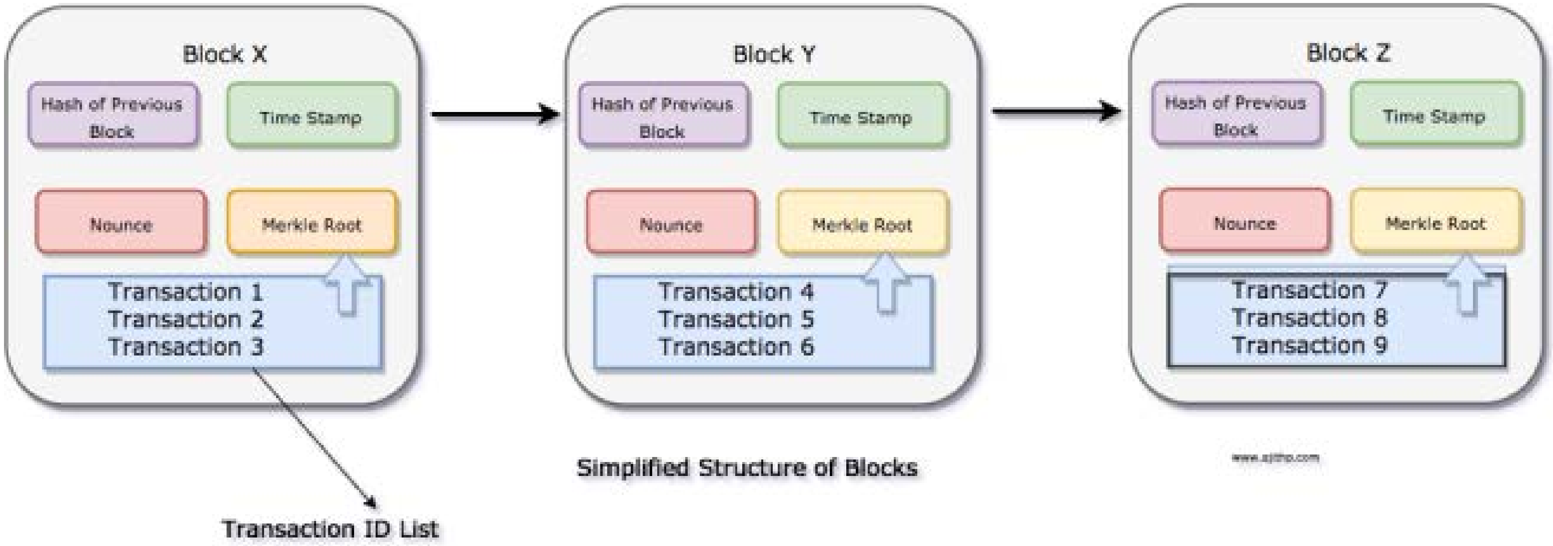
Comparison

Decrypt

Blockchain

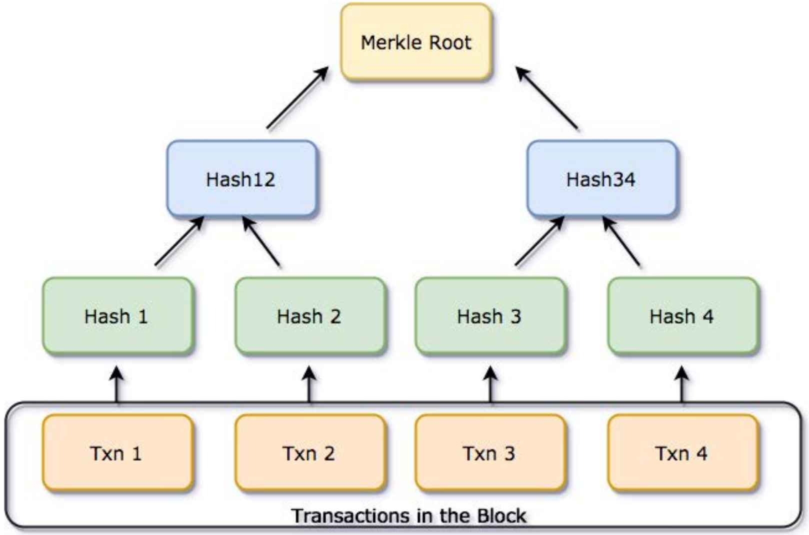

Pool of Unconfirmed Transactions
Nick 2BTC Kate
Maria 3BTC Helen
George 1BTC John
Rob 5BTC Peter
Bitcoin node
Block 303
Nick 2BTC Kate
Maria 3BTC Helen
next block
Block 300
Transactions
Block 301
Transactions
Block 302
Transactions
blockchain

Blockchain



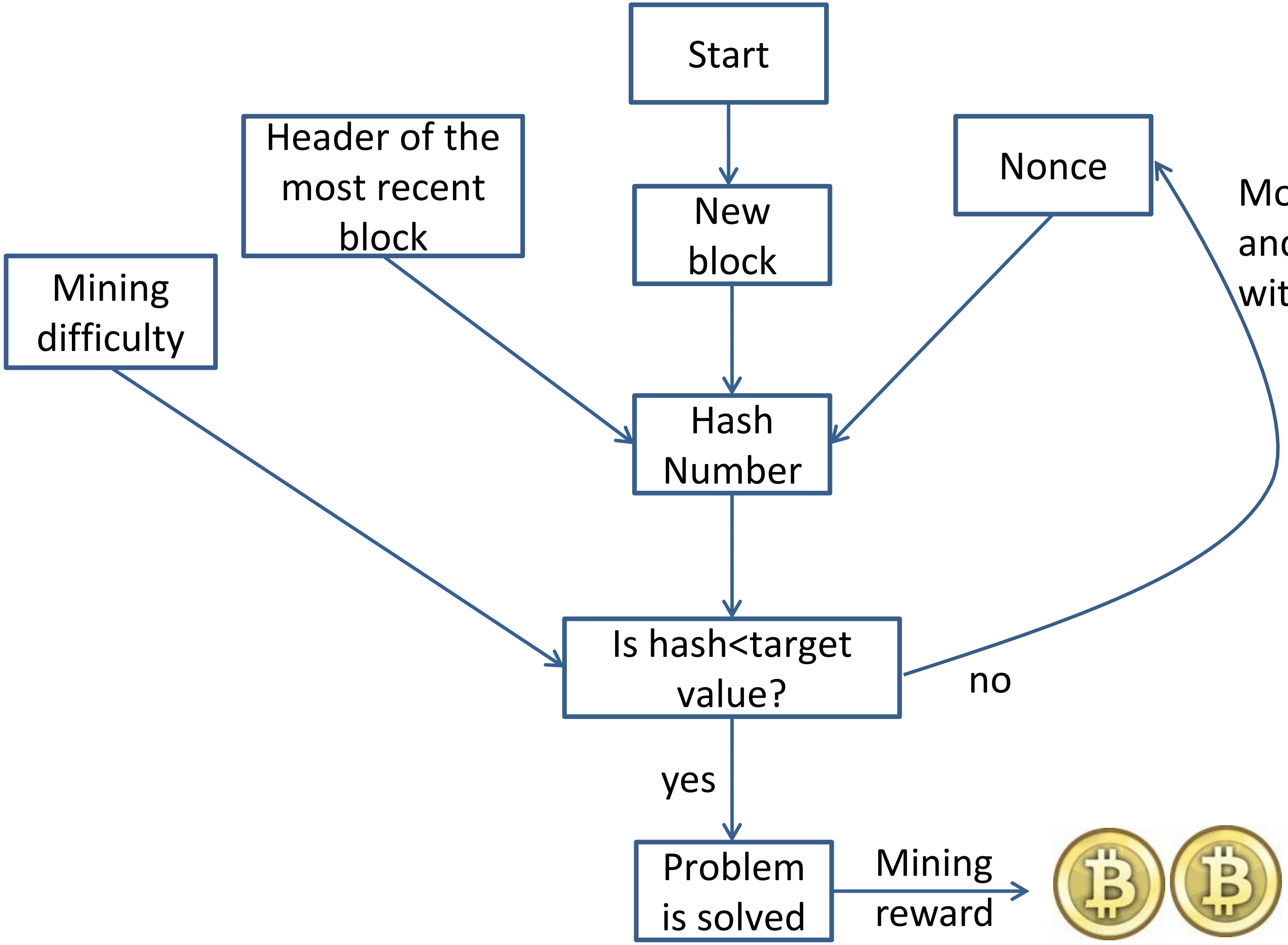
Simplified Structure of Blocks

www.ajithp.com



www.ajithp.com

Blockchain



Start

New block

Header of the most recent block

Mining difficulty

Nonce

Modify nonce and try again with a new hash

Hash Number

Is hash<target value?

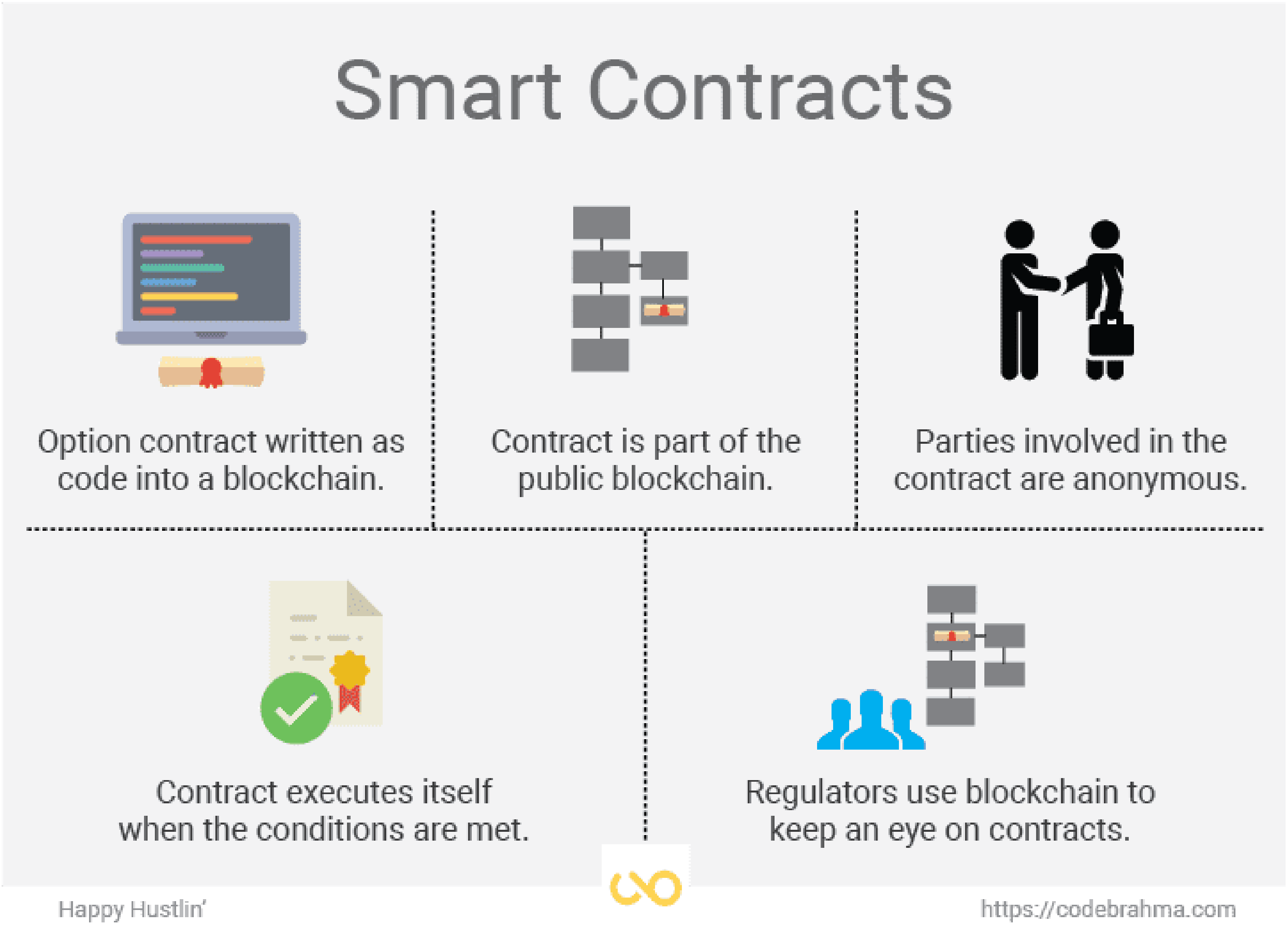
no

yes

Problem is solved

Mining reward

Blockchain



Smart Contracts

Option contract written as code into a blockchain.

Contract is part of the public blockchain.

Parties involved in the contract are anonymous.

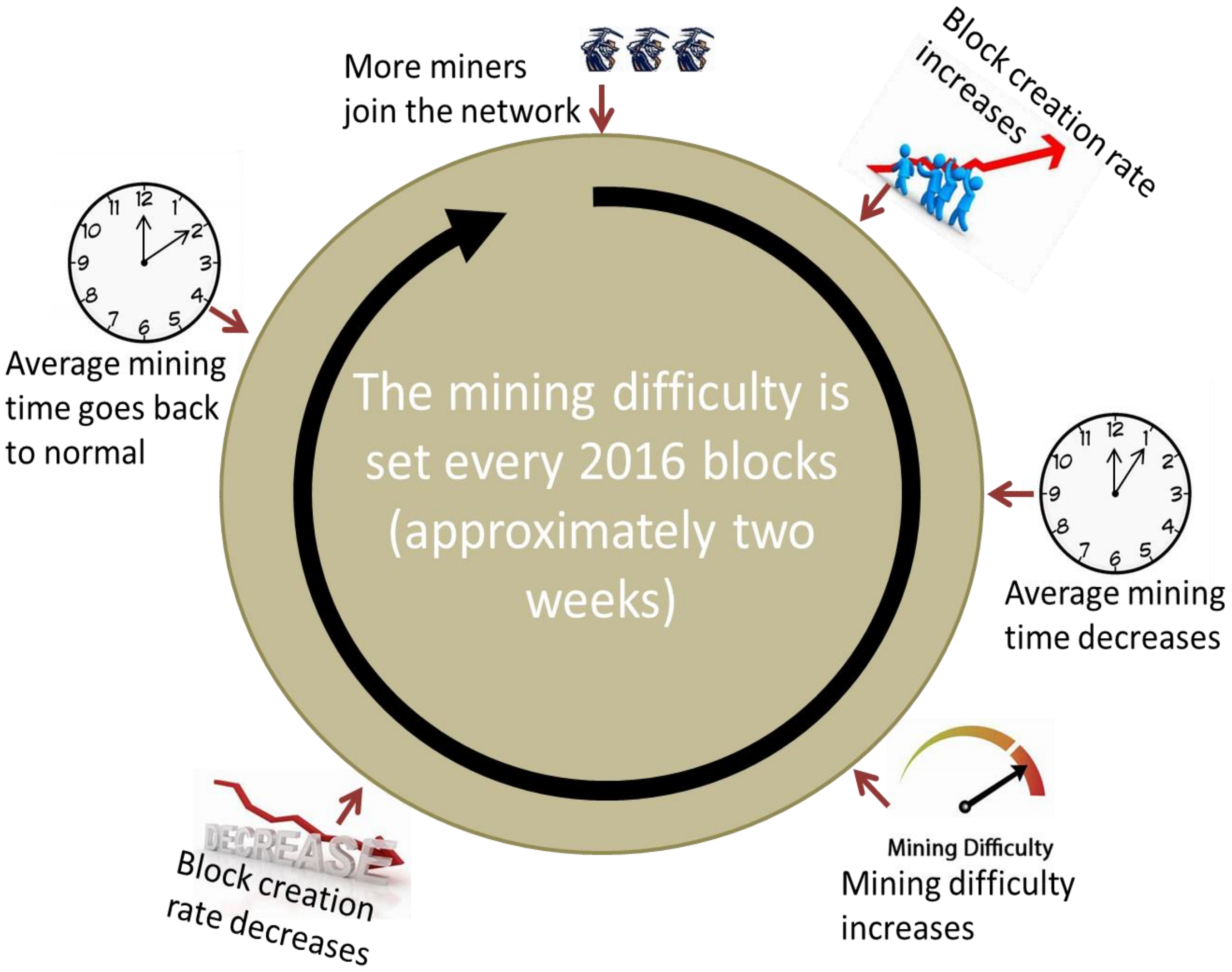
Contract executes itself when the conditions are met.

Regulators use blockchain to keep an eye on contracts.

Happy Hustlin'

https://codebrahma.com

Blockchain



The mining difficulty is set every 2016 blocks (approximately two weeks)

More miners join the network

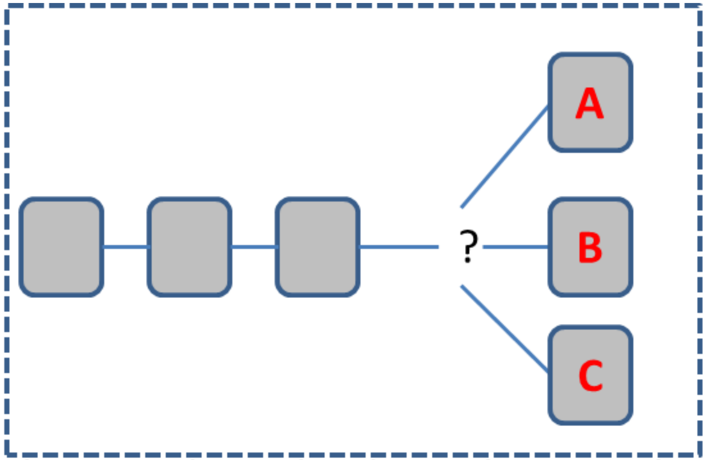
Block creation rate increases

Average mining time decreases

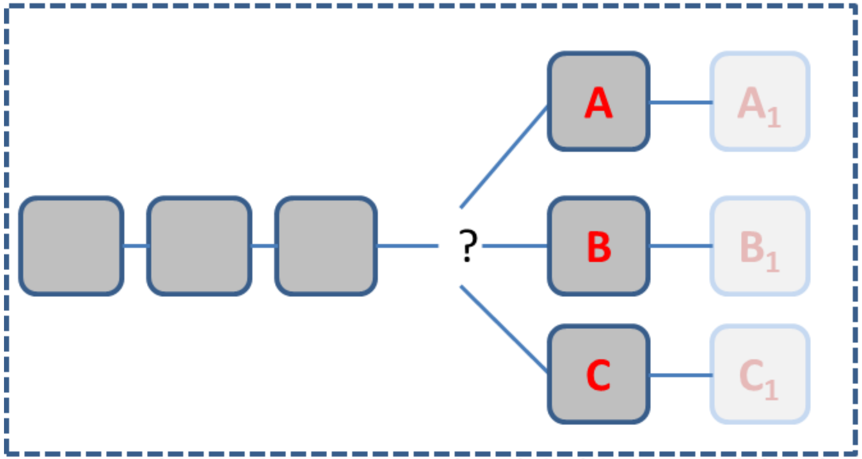
Mining difficulty increases

Block creation rate decreases

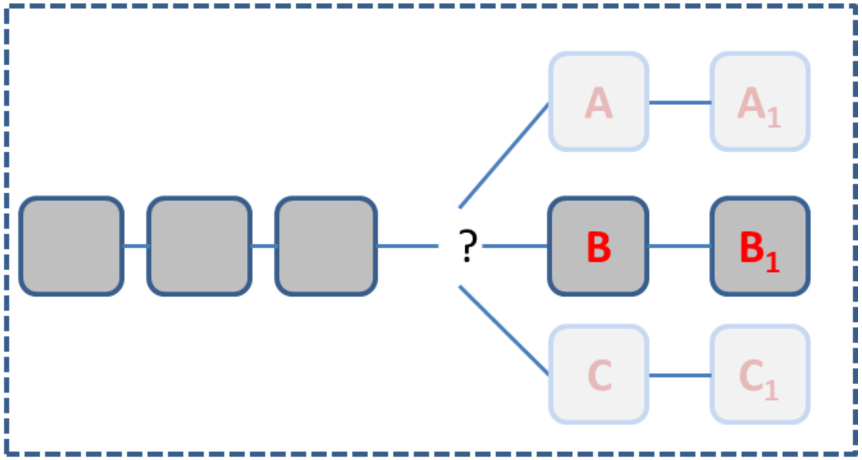
Average mining time goes back to normal



Three nodes solved simultaneously the mathematical problem

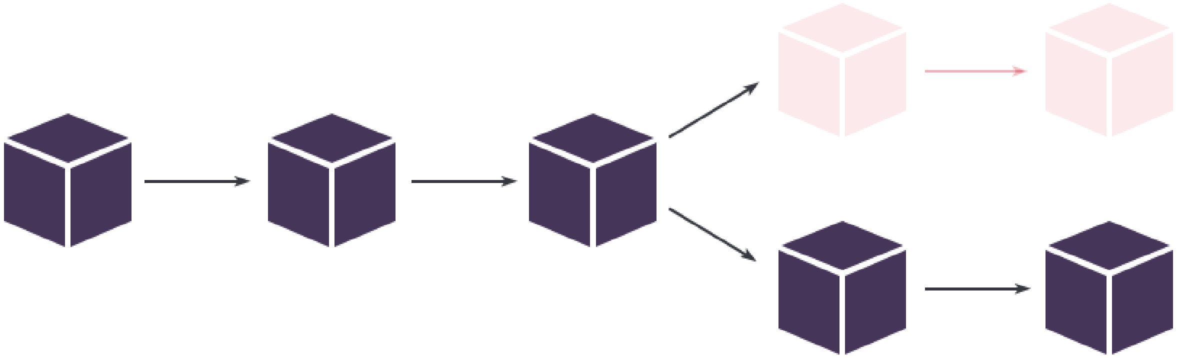


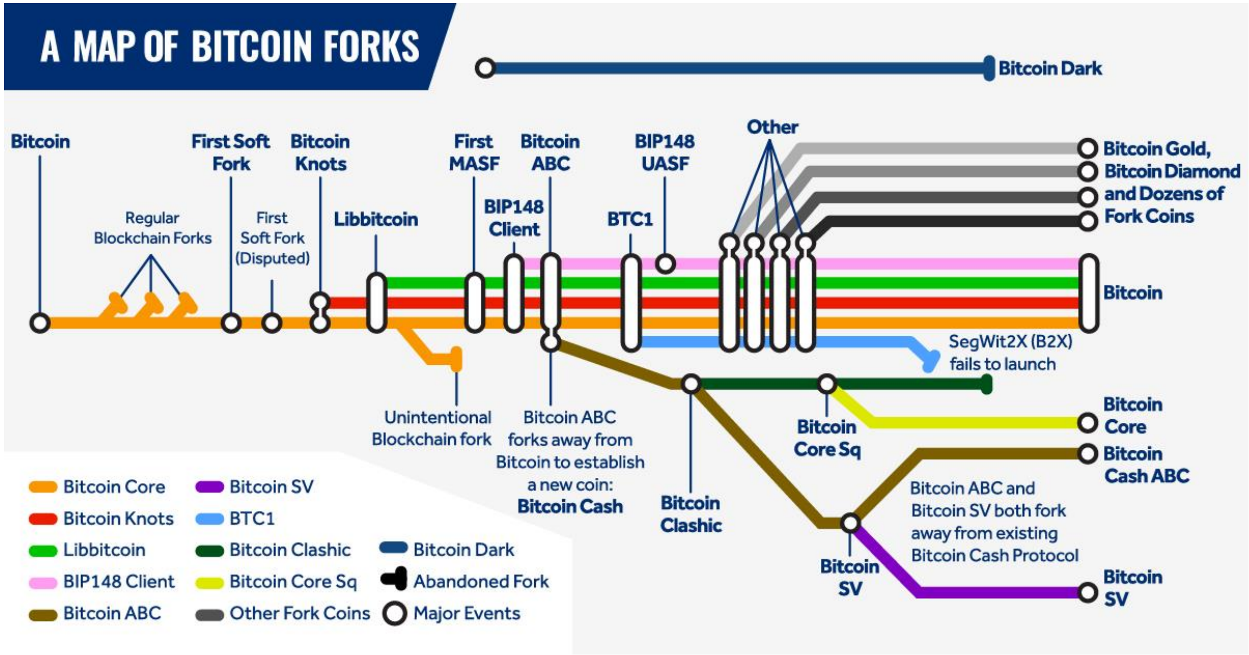
Each node tries to build the next block



All network node adopt the longest chain (i.e. the one containing B and B1)

Blockchain forks





***Source**: www.visualcapitalist.com*

Perceived Pros

- Seismic shift in finance and business
  - Security and anonymity
  - Protection from fraud, identity theft and counterfeit products
  - Very low transaction fees: Instant, borderless, cost efficient payments and fund transfers
  - It offers e-commerce businesses and traders a lot of autonomy with no third-party interruptions
- Blockchain is viewed as a democracy tech
  - Blockchain ideal world is one in which all economic activity and human interactions are subject to libertarian decentralisation
  - Decentralisation to resist "authoritarianism and evil concentrations of power"
  - Blockchain-based governance
  - "Code is the law"
  - "Blockchain for good"

“Blockchain for good”: Universal Basic Income

- Simplify the welfare system, provide a stable income, replace the current system of social security, unemployment and pension payments, child support and tax spendings
- Several UBI Blockchain initiatives
  - *SwiftDemand*, *Mannabase*, *Solidar*, *Circle*, *Manna*, *Grantcoin*, *Democracy Earth*, *Big Foundation*, *projectUBU*
- Issue their own currency in the form of tokens: instead of recirculating existing money in the economy, they generate new value by minting a new currency.
- Minimum Viable Economy: build enough of an ecosystem around a token
  - Monetary Policy (incentives to accept and spend tokens, airdrops, etc),
  - Liquidity (exchange the token for another currency, stablecoins)
- Identity Verification & Anti-Fraud Challenges: voting and social trust
- Sustainability: align the developers’ interest with their users’ interests

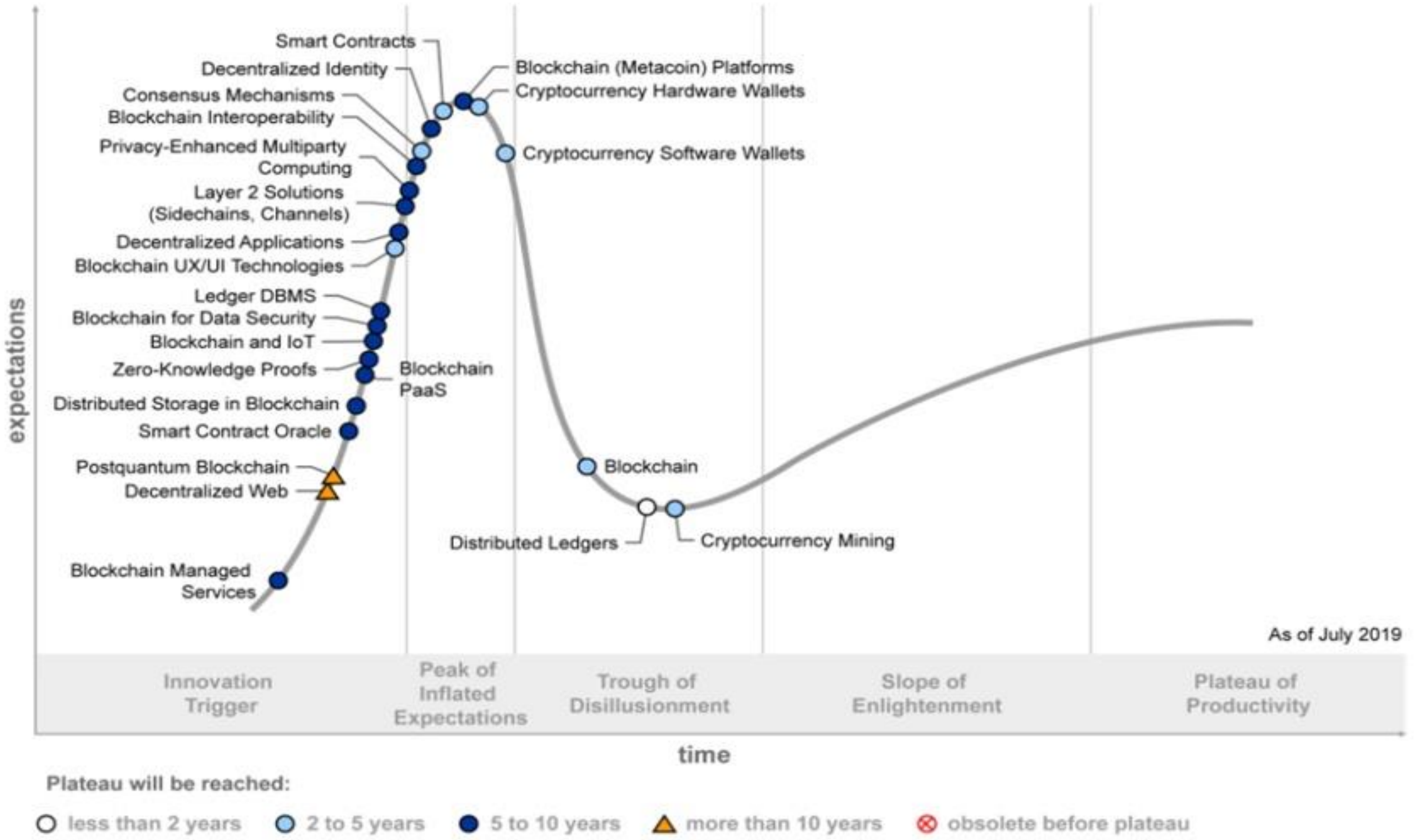
"Blockchain for good": Impact Investment

- "Impact Tokens"
  - Claim to represent a UN Sustainable Development Goal-related impact, usually in the form of a quantified, unit-based measurement metric, which is linked to its origin
  - Can be used to make performance-based payments, track impacts through supply chains or substantiate claims on supporting SDGs
- Blockchain supports tracking progress and verifying that milestones have been met.
  - **Trust**: automate and accelerate impact measurement and verification, enabling credible accounting of impacts
  - **Attribution of impact**: allocation of an impact-related claim to an investor, often risking the "double-counting" of claims. Impact tokens can be used to track the impact of an investment
  - **Impact monetisation** acceleration, transaction costs removed, transparency and open source to support a broad stakeholder base.

“Blockchain for good”: Impact Investment

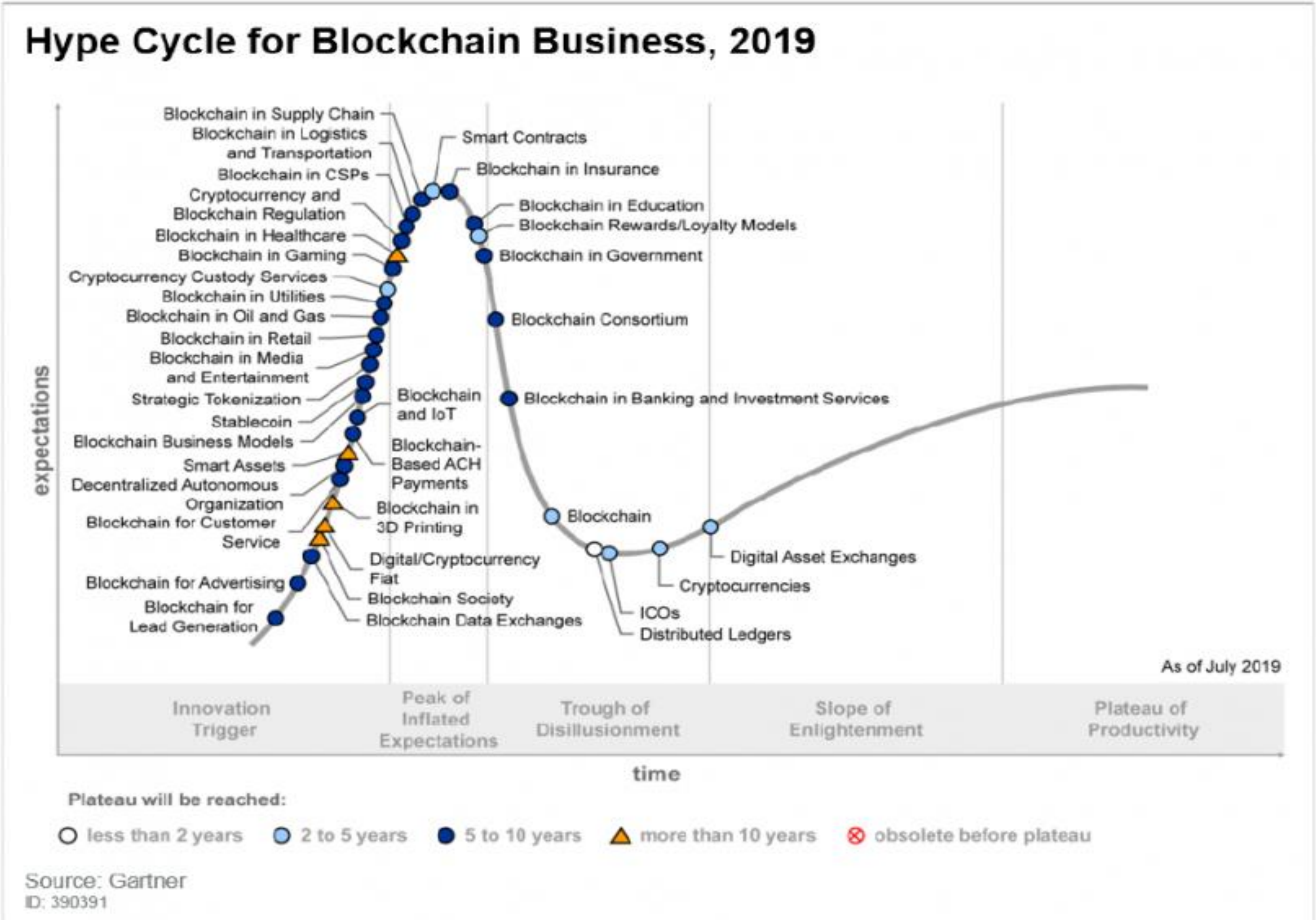
- UN’s Principles for Responsible Investment initiative has listed a variety of areas, including energy trading systems, secure recording of educational certificates for local schools and storing and access to medical data
- **SolarCoin (**SLR), one of the earliest impact tokens. Incentivize solar electricity by rewarding the generators of solar electricity to reduce the cost of electricity production. 1SLR/1MWh . “**Proof of impact**” verification protocol.
- **Sun Exchange** use of impact tokens to fund new solar projects in Africa.
- **ClimateChainCoalition** (UNFCCC Secretariat).
- **GainForest** project explores the conversion of high-resolution satellite data into carbon stock data and impact tokens. Smart contract architecture connects donors from private and public sector with caretakers.
- A blockchain pilot captures and verifies data from **greenhouse gas emission reduction projects** to make the resulting positive impact tangible at the moment it is physically achieved.
- **Building Blocks** platform by the **World Food Programme** to make payments to refugees. Blockchain technology provides unique digital identity to eligible beneficiaries and cut transaction costs for cash transfers.

Blockchain Technologies



- Gartner expects blockchain to become fully scalable technically and operationally by 2028

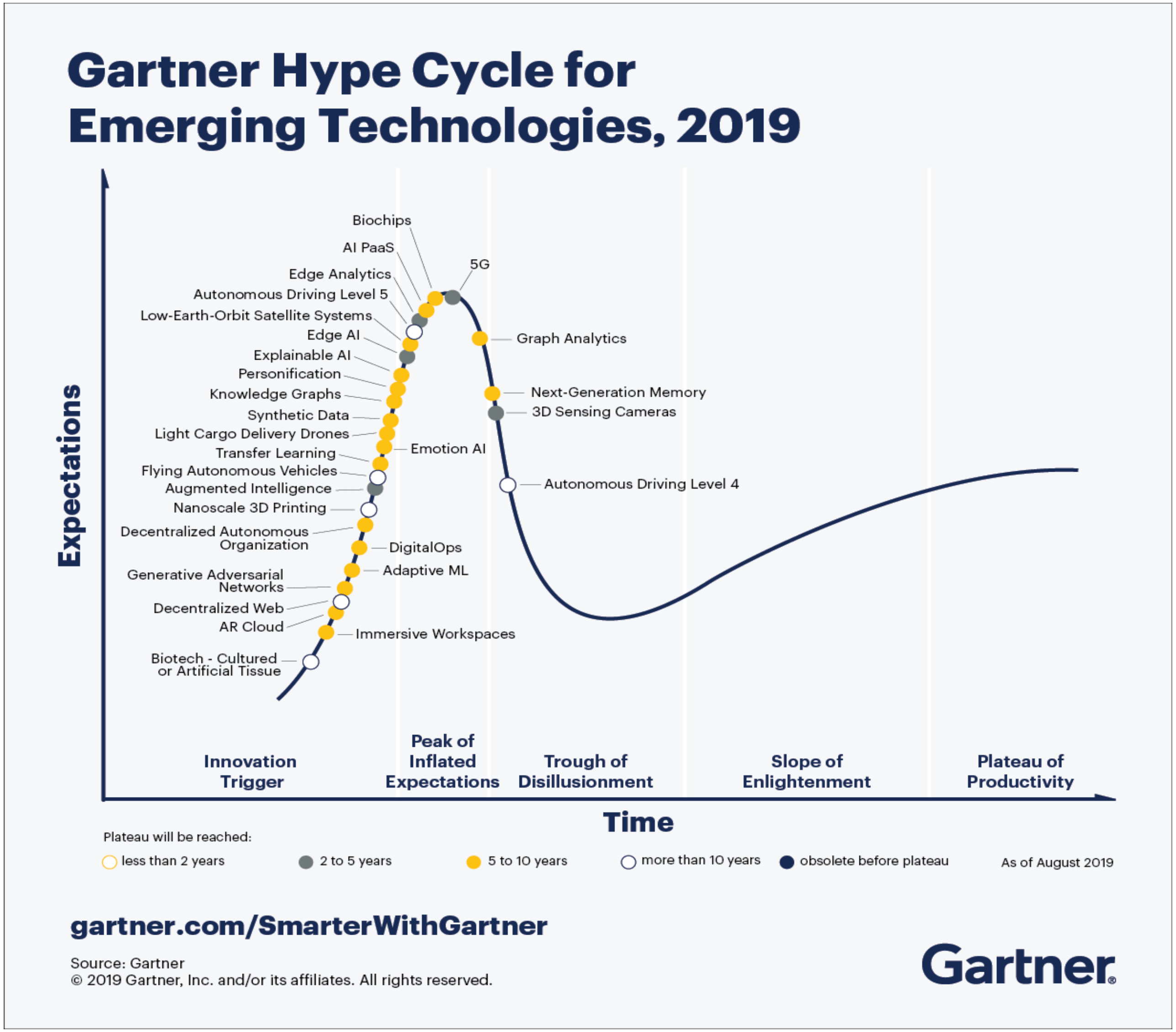
Blockchain Applications



Hype Cycle for Blockchain Business, 2019

Source: Gartner
ID: 390391

Blockchain Technologies



Gartner Hype Cycle for Emerging Technologies, 2019

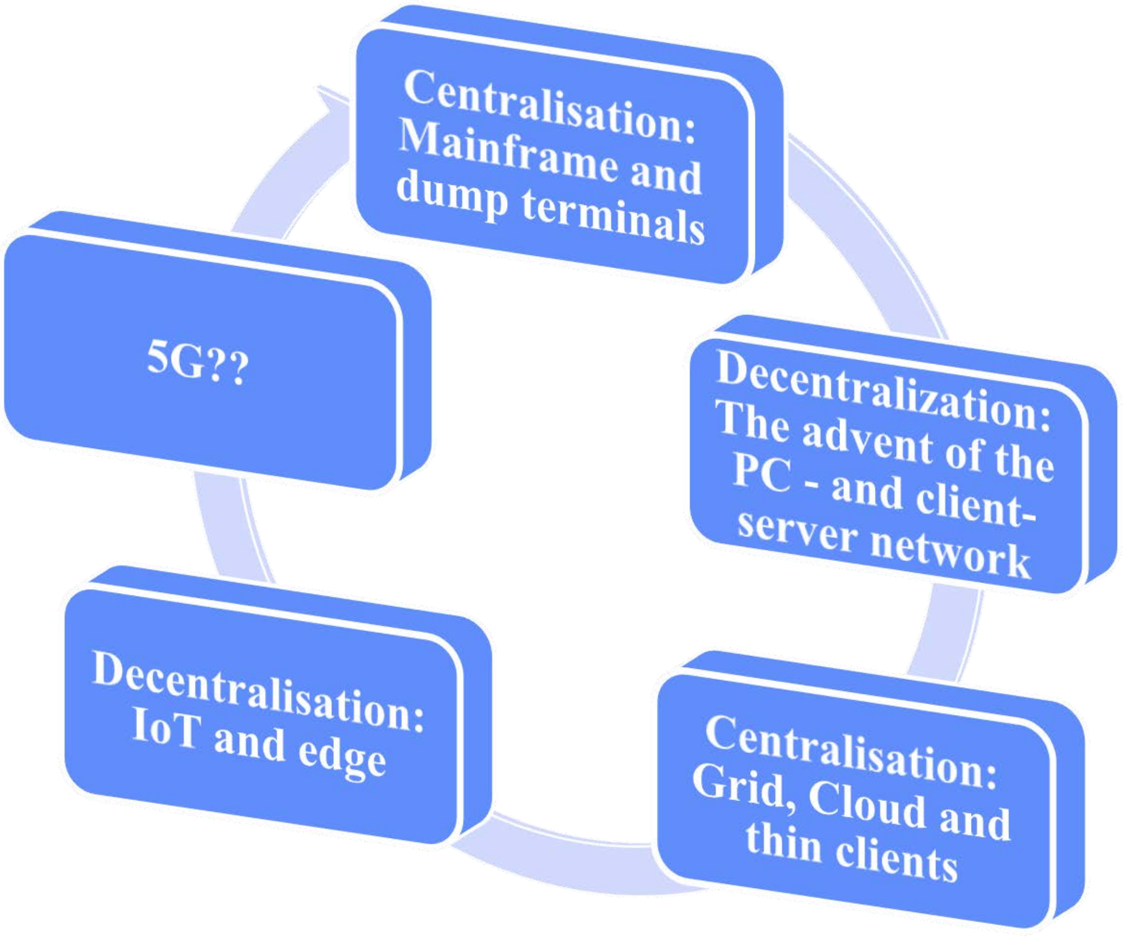
gartner.com/SmarterWithGartner

Source: Gartner

Technological Support

- Tech industry already is a major hub for crypto and Blockchain applications.
- IBM
  - HyperLedger Fabric. Digital Trade Chain Consortium consisting of Deutsche Bank, HSBC, KBC, Natixis, Rabobank, Societe Generale and Unicredit.
  - IBM Blockchain World Wire: 72 countries, with 47 currencies. 6 global banks to issue their own *stablecoins* on IBM Blockchain World Wire
- Google to introduce open source integrations for decentralized apps built with the blockchain platforms Hyperledger, Fabric and Ethereum in the Google Cloud Product marketplace
- Microsoft, Dell and Dish, which are now accepting cryptocurrencies as payment
- Facebook Libra: Permissioned. With 2.4 billion people using Facebook each month, Libra could be a financial game changer

Distributed Systems Cycle



Centralisation: Mainframe and dump terminals

Decentralization: The advent of the PC - and client-server network

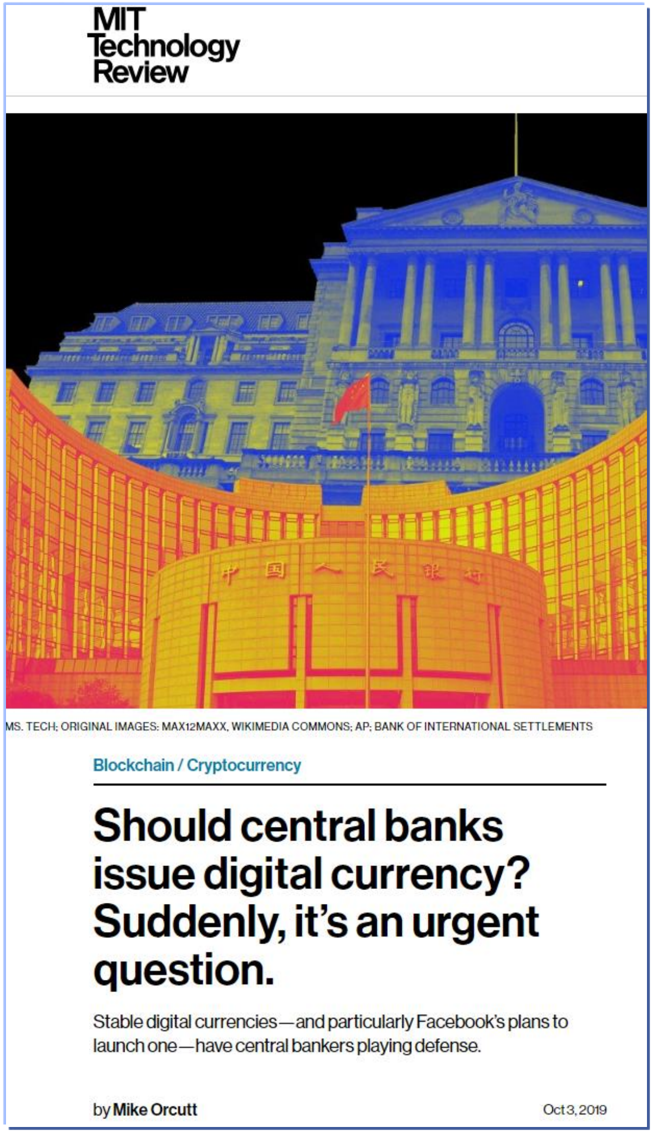
Centralisation: Grid, Cloud and thin clients

Decentralisation: IoT and edge

5G??

Banking

- Blockchain in several key areas in banking and investments services, primarily focused on **permissioned ledgers**.
- Bank of America holder of most blockchain technology patents
- Gartner sites banking as the most mature industry for Blockchain
  - *“We also expect continued developments in the creation and acceptance of digital tokens. However considerable work needs to be completed in nontechnology-related activities such as* ***standards, regulatory frameworks and organization structures*** *for blockchain capabilities to reach the Plateau of Productivity – the point at which mainstream adoption takes off, in this industry.”*



MIT Technology Review

MS. TECH; ORIGINAL IMAGES: MAX12MAXX, WIKIMEDIA COMMONS; AP; BANK OF INTERNATIONAL SETTLEMENTS

Blockchain / Cryptocurrency

Should central banks issue digital currency? Suddenly, it’s an urgent question.

Stable digital currencies—and particularly Facebook’s plans to launch one—have central bankers playing defense.

by **Mike Orcutt**

Oct 3, 2019

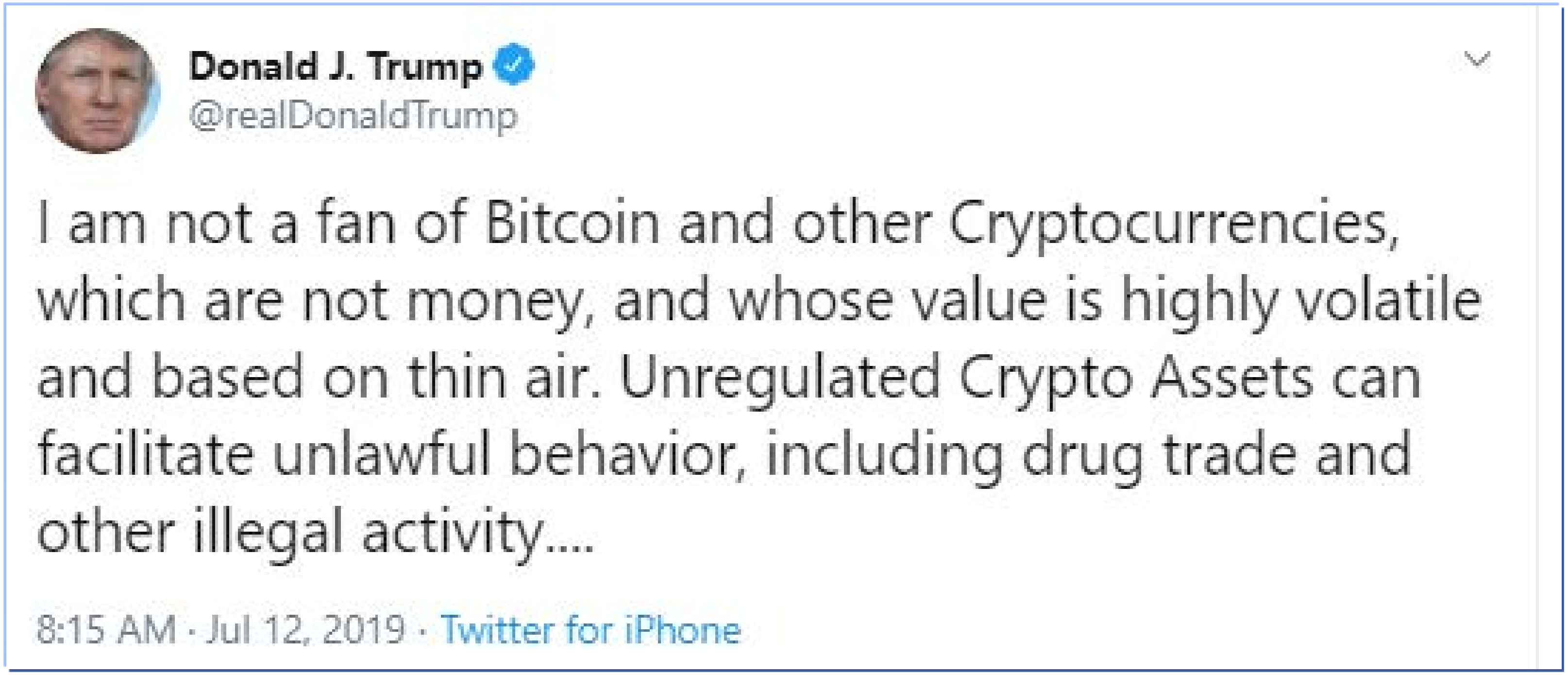
Regulation: G20

- G20 leaders issued a joint declaration in which they pledged support for the Financial Action Task Force's (FATF) recommendations regarding the regulation of crypto assets.

> *"...while crypto-assets do not pose a threat to global financial stability ...we are closely monitoring developments and remain vigilant to existing and emerging risks. ... We welcome ongoing work by the Financial Stability Board (FSB) and other standard setting bodies and ask them to advise on additional multilateral responses as needed".*

Regulation: US

- Regulatory frameworks proposed by:
  - The U.S. Internal Revenue Service (IRS)
  - The U.S. Commodity Futures Trading Commission
  - The U.S. Securities Exchange Commission (SEC)
  - The US Financial Industry Regulatory Authority (FINRA)



Donald J. Trump
@realDonaldTrump

I am not a fan of Bitcoin and other Cryptocurrencies, which are not money, and whose value is highly volatile and based on thin air. Unregulated Crypto Assets can facilitate unlawful behavior, including drug trade and other illegal activity....

8:15 AM · Jul 12, 2019 · Twitter for iPhone

Regulation: EU

- Feb 2018, Working Groups
  - Blockchain Policy and Framework Conditions
  - Use Cases and Transition Scenarios

- No specific legislation regarding cryptocurrencies at the EU Parliament level. Cryptocurrencies are broadly considered legal across the bloc, exchange regulations depend on individual member states.
- Single Supervisory Mechanism proposed
- Report on “Cryptocurrencies and blockchain - Legal context and implications for financial crime, money laundering and tax evasion”, Policy Department for Economic, Scientific and Quality of Life Policies

Regulation: China

- Blockchain technology strong (e.g. Shenzhen subway)
- 2017 ban on all ICOs, crypto trading, crypto exchanges etc
  - Making of new digital currency for existing cryptocurrencies continued

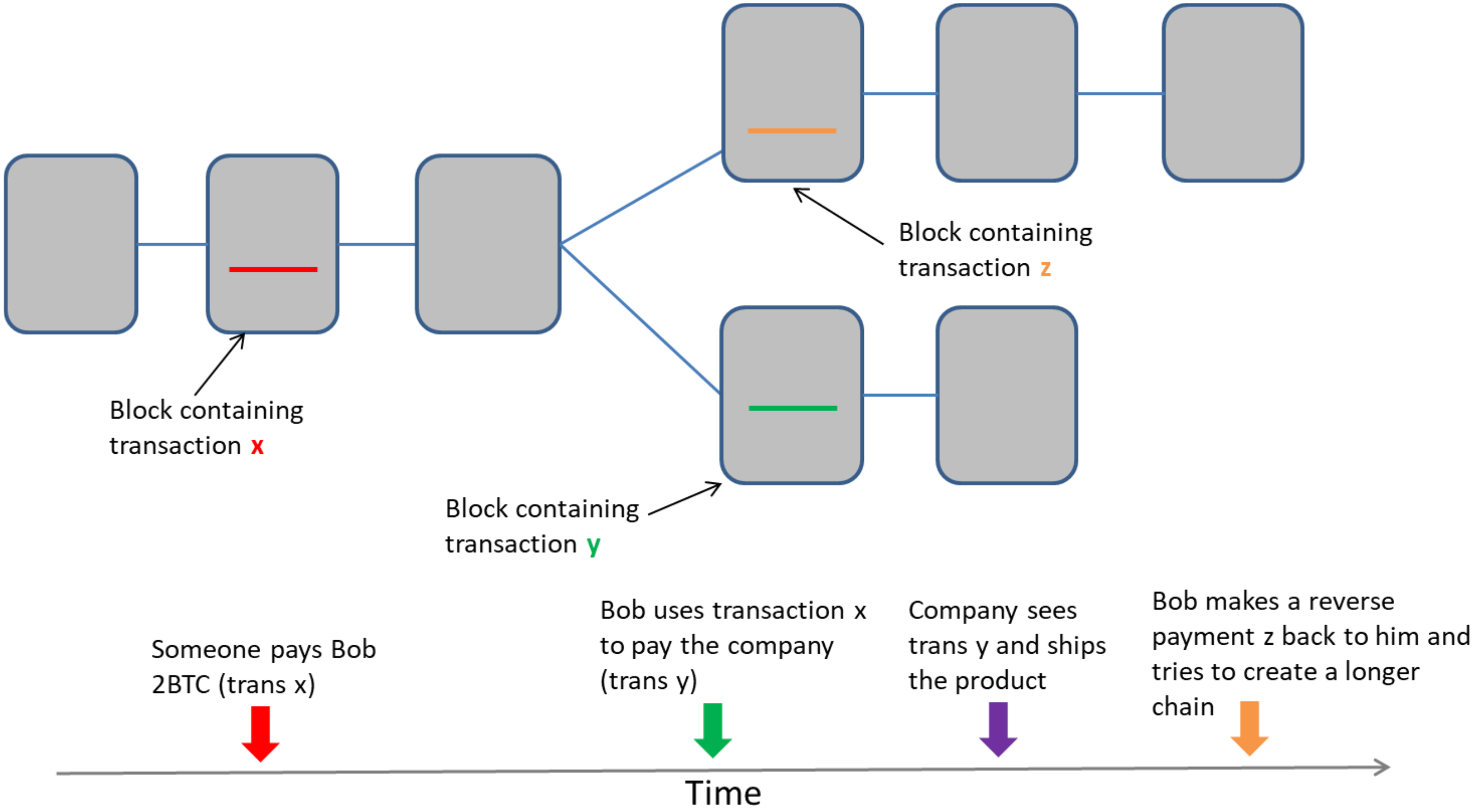
- October 2019 ban reversed. President Xi directed China to expedite issuing its own digital currency to beat the U.S.-based Facebook’s launch of Libra Coin
- Stock market frenzy followed. Nov 6 People’s Daily warns about the need to avoid speculative behavior in the blockchain sector.

Reality Check: Pitfalls and Fallacies

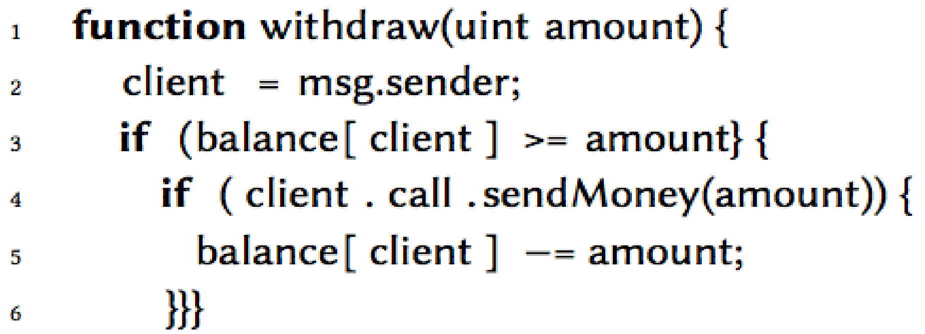
- Democratic?
  - It provides governments with an almost perfect means of tracking individual and business financial activity.
  - Hard forks can be authoritarian
  - Code is the law: trust?
- Not secure at all
- Immense energy consumption
- Massive centralisation of power among cryptocurrency “miners,” exchanges, developers

Double Spent Attack

- Transactions become more secure with time
- 51% attack. Jan 2019 CoinBase $1.1M

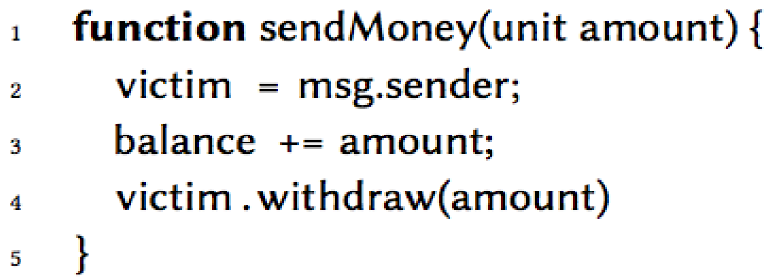

Block containing transaction z
Block containing transaction x
Block containing transaction y
Someone pays Bob 2BTC (trans x)
Bob uses transaction x to pay the company (trans y)
Company sees trans y and ships the product
Bob makes a reverse payment z back to him and tries to create a longer chain
Time

Decentralised Autonomous Organisation Attack



```
function withdraw(uint amount) {
    client  = msg.sender;
    if  (balance[ client ]  >= amount} {
       if  ( client . call .sendMoney(amount)) {
          balance[ client ]  −= amount;
       }}}
```

Fig. 1. Pseudocode for DAO-like contract



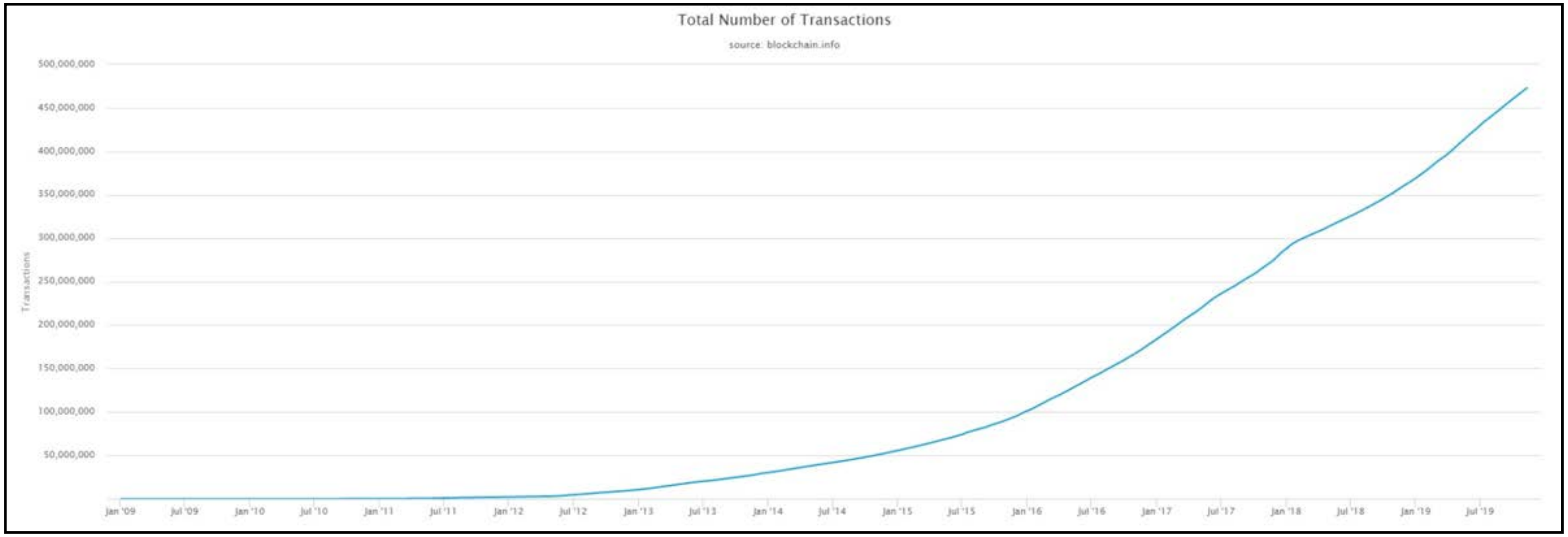
```
function sendMoney(unit amount) {
    victim  = msg.sender;
    balance  += amount;
    victim .withdraw(amount)
}
```

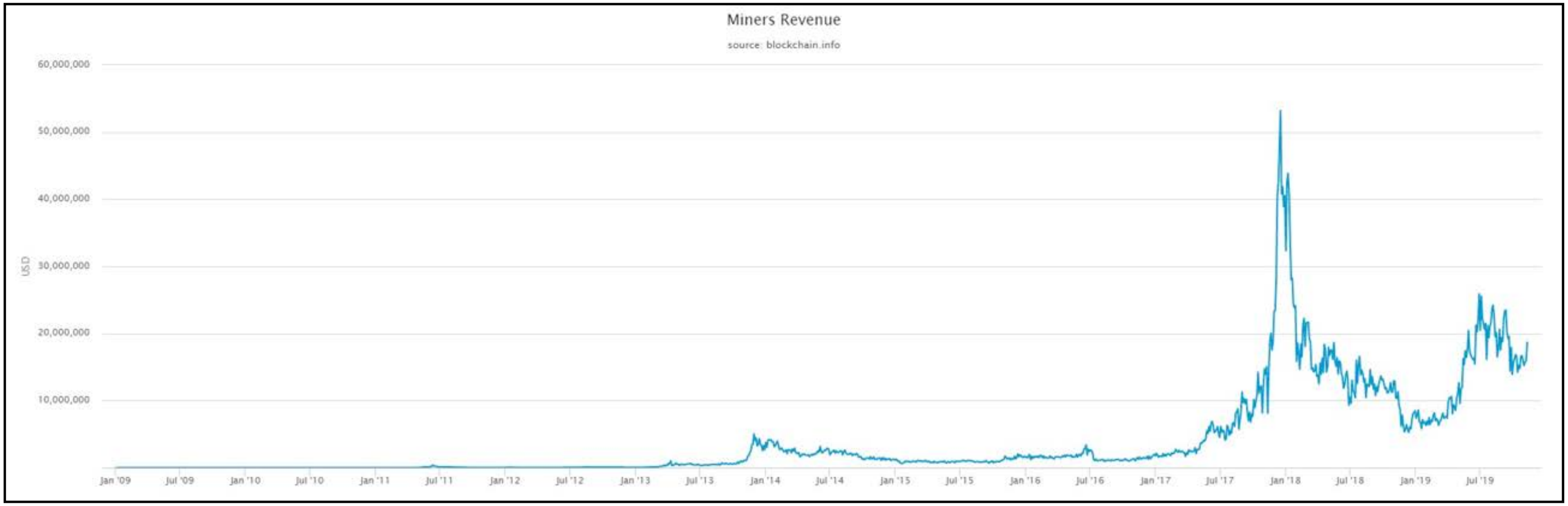
Fig. 2. Pseudocode for DAO-like exploit

- June 2016 within a few hours, 3.6 million ETH were stolen, the equivalent of $70 million

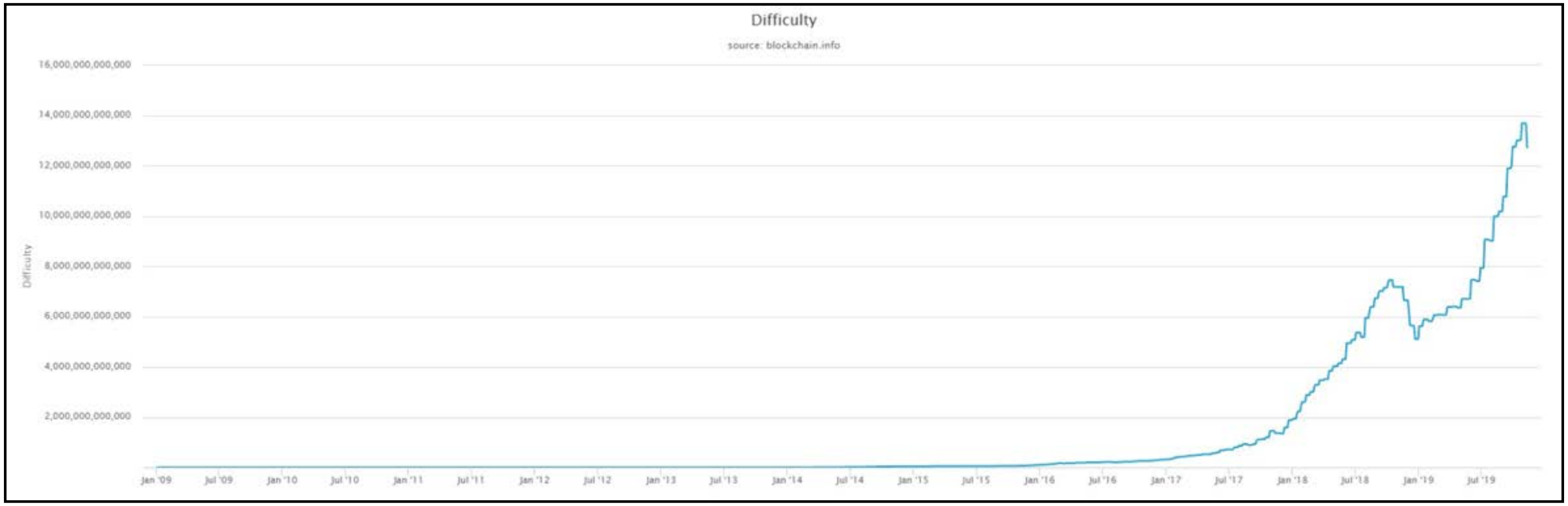
Energy

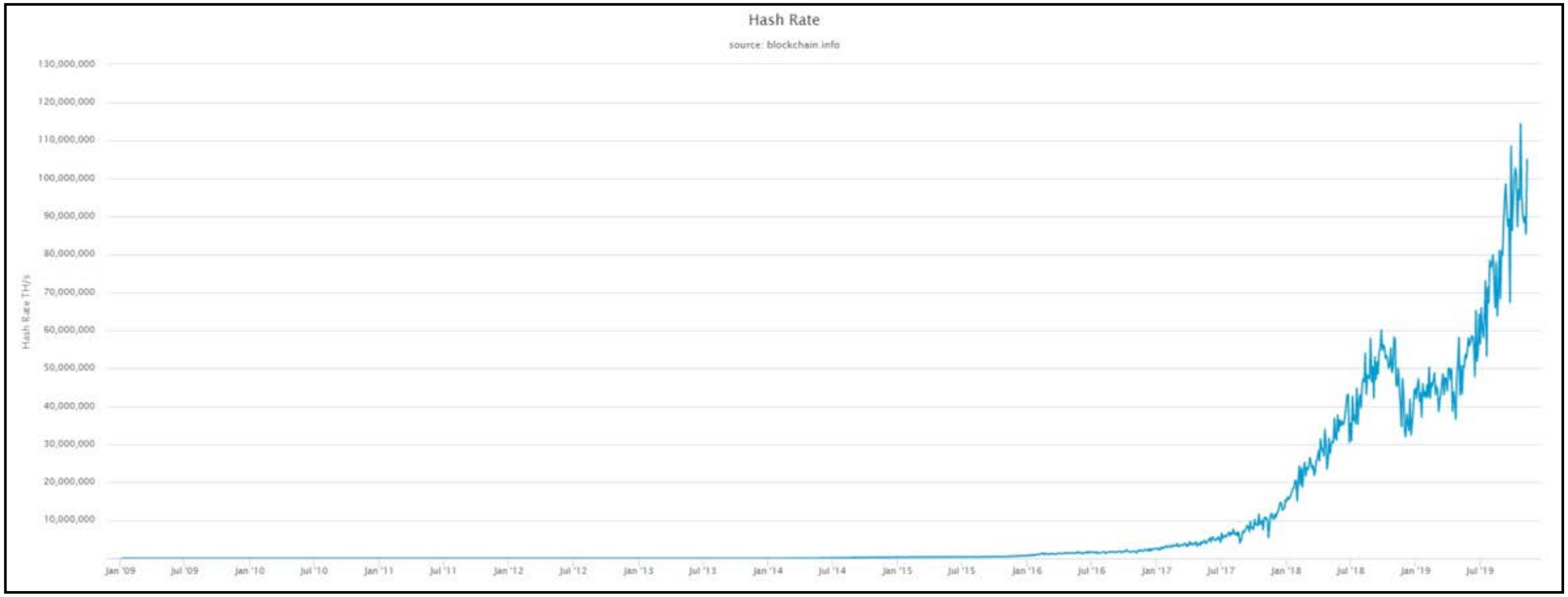
- Bitcoin is using around seven gigawatts of electricity, equal to 0.21% of the world's supply.
- That is as much power as would be generated by seven Dungeness nuclear power plants at once.
- Energy use is doubling every six months.
- Far more energy per transaction than all the world's banks put together, when considering the amount of energy used by data centres.
- £1M/day for Ethereum mining





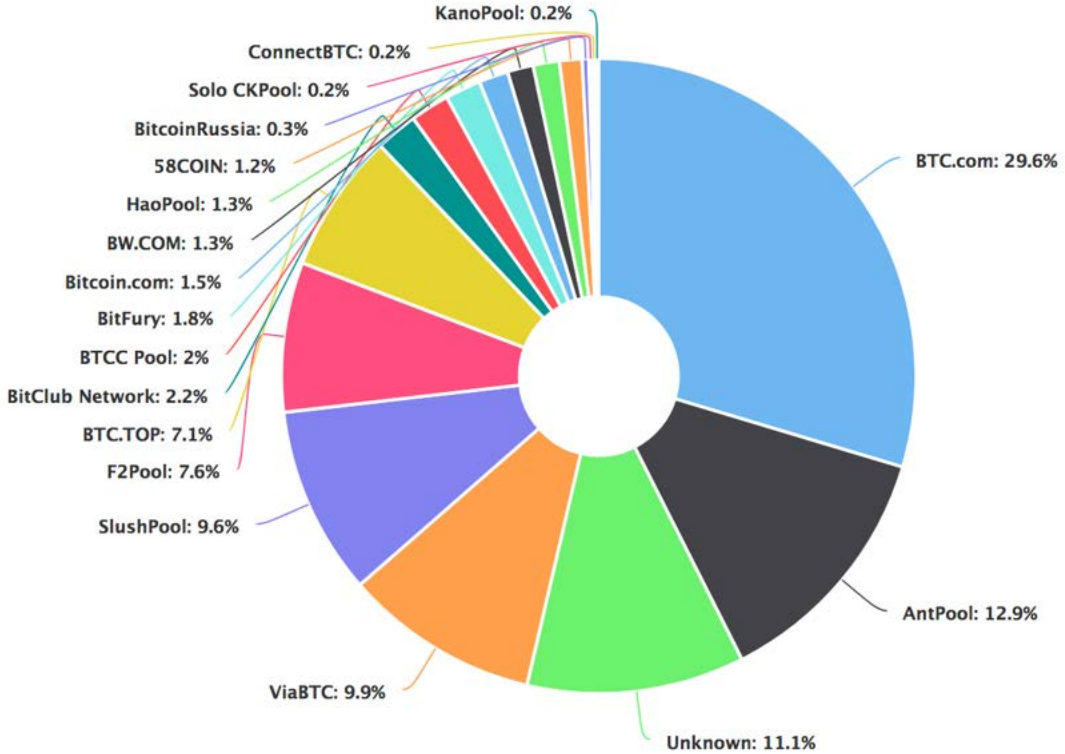
Source: *www.blockchain.com*

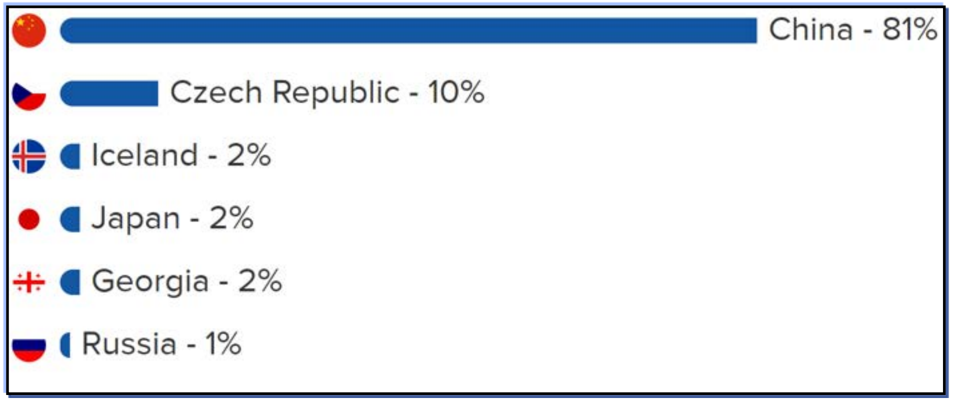




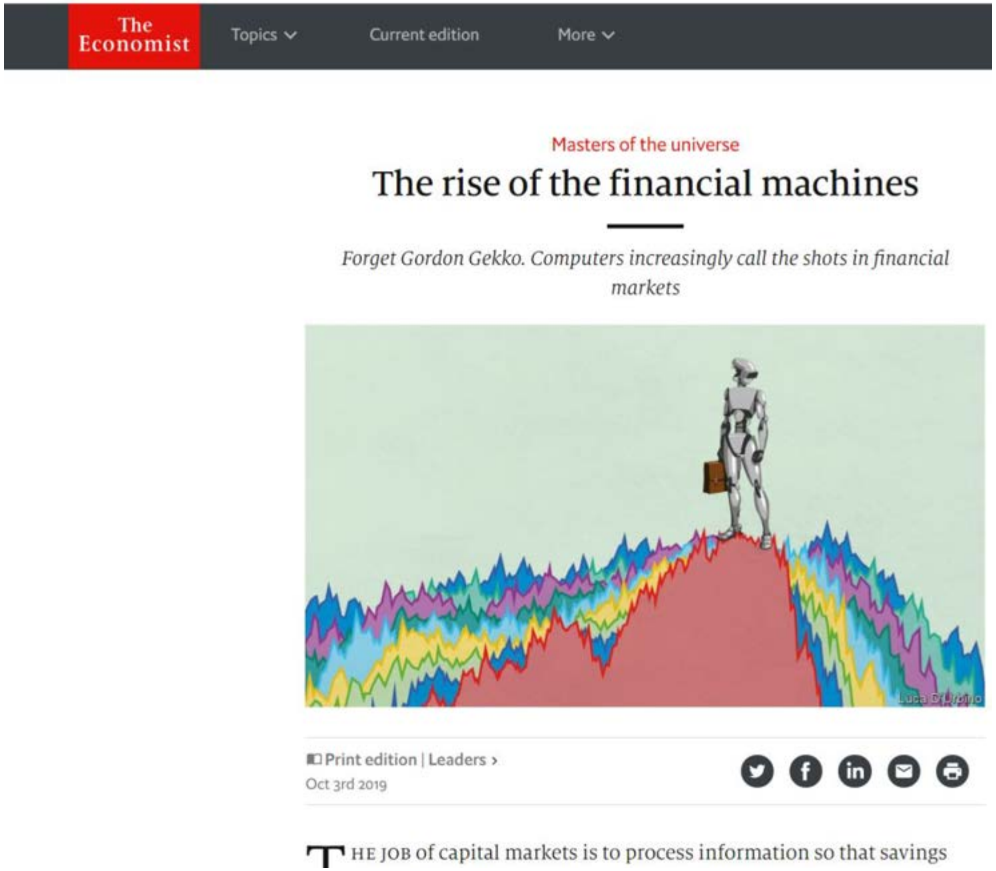
Source: *www.blockchain.com*

Hash Rate and Mining Distribution





Source: *www.blockchain.com*



Masters of the universe

The rise of the financial machines

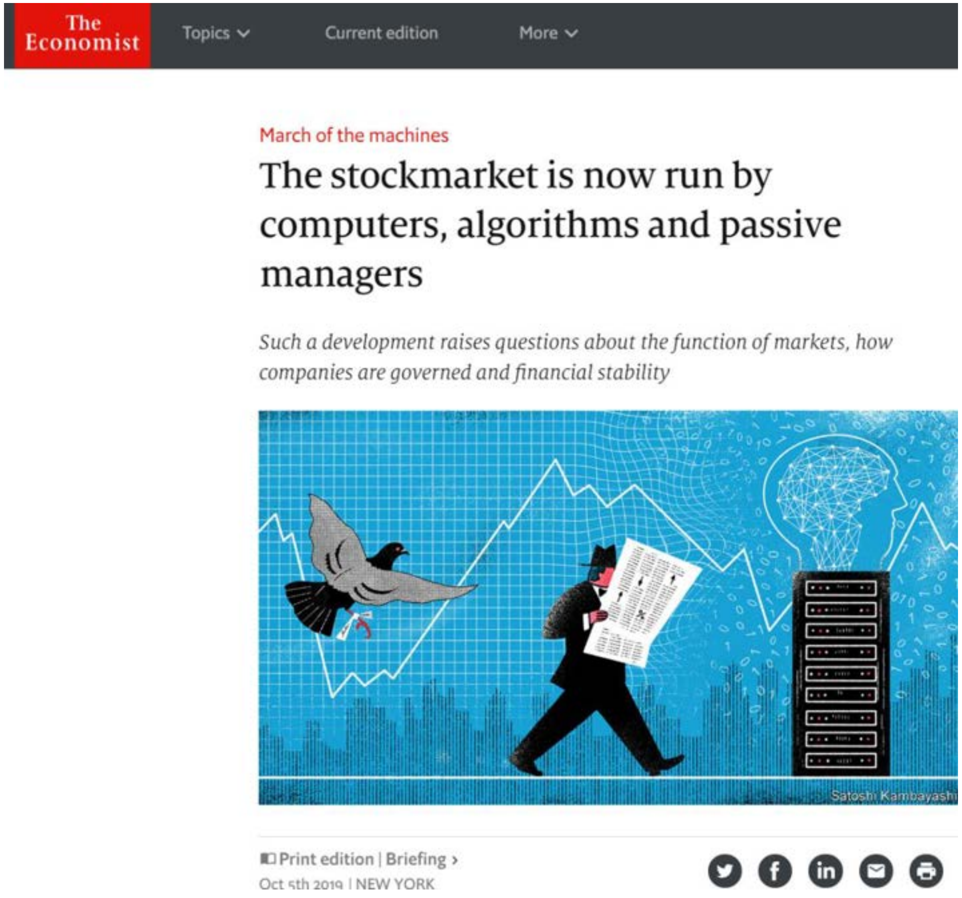
Forget Gordon Gekko. Computers increasingly call the shots in financial markets

Luca D'Urbino

Print edition | Leaders ›

Oct 3rd 2019

THE JOB of capital markets is to process information so that savings



March of the machines

The stockmarket is now run by computers, algorithms and passive managers

Such a development raises questions about the function of markets, how companies are governed and financial stability

Satoshi Kambayashi

Print edition | Briefing ›

Oct 5th 2019 | NEW YORK

- Performance rests more on processing power and data
- Explainability in AI
- Large Scale Complex System

Thank You