Rotman
School of Management

Capital Markets Institute

The Blockchain Identity

Campbell R. Harvey

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Revised September 16, 2016

Imagine …

Closing on a house with

- No title insurance
- Minimal legal
- No title search
- Simply consult a secure ledger that establishes the person you are buying the house from actually owns it

Imagine …

Buying and selling stock with t0 settlement

- Today is t+3 no different than the 1920s
- All stock transactions would reside in a secure ledger devoted to a company's equity

Imagine …

Instantly transferring funds between accounts

- Transfers are not immediate today – even within your own bank!
- Transfers are secure and inexpensive

FINANCIAL TIMES

May 24, 2016 7:13 pm

The growing threat from online bank robbers

Share Author alerts Print Clip Gift Article Comments

A series of heists forces the Swift cross border network to tighten up

Imagine …

The end of counterfeiting

- Massive number of counterfeit bills in circulation

Imagine …

The end of counterfeiting

- Massive number of counterfeit bills in circulation

Imagine …

The end of counterfeiting

- Not just North Korea
- Peru is the world leader

'Counterfeiting is an art': Peruvian gang of master fabricators churns out $100 bills

http://www.theguardian.com/world/2016/mar/31/counterfeiting-peruvian-gang-fabricating-fake-100-bills

Imagine …

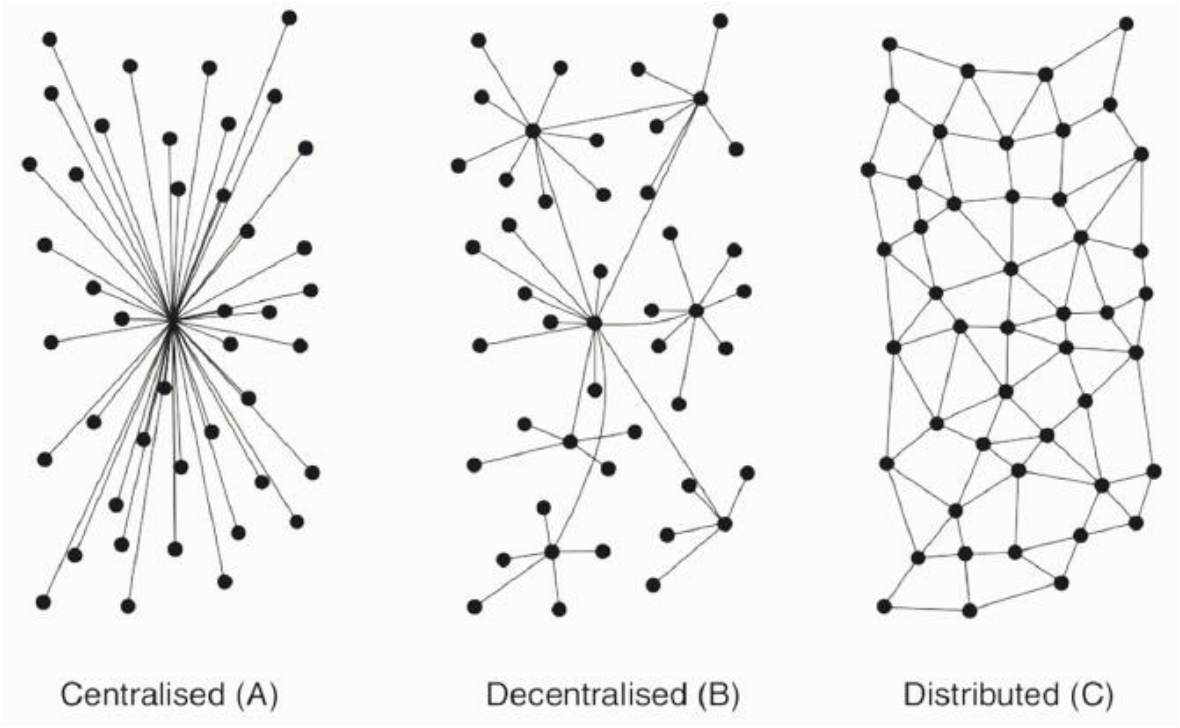
Starting your car with your thumb print

- A secure ledger is checked to verify that you own the car

Overview

What is it? A blockchain is

- A distributed, secure, transparent ledger that establishes ownership and allows for the efficient exchange of ownership



Paul Baran, 1964. On distributed communications. RAND.

Overview

What is it? A blockchain is

- Transactions are grouped together into blocks. Current transactions are cryptographically linked (chained) to past transactions (and future transactions)
- Blockchains can be private or public

Overview

Definitions

- A *public blockchain* is a blockchain, in which there are no restrictions on reading blockchain data (which still may be encrypted) and submitting transactions for inclusion into the blockchain.
- A *private blockchain* is a blockchain, in which direct access to blockchain data and submitting transactions is limited to a predefined list of entities.

http://bitfury.com/white-papers-research

In the news….

R3CEV includes:

- Goldman
- JPMorgan
- Credit Suisse
- …

September 15, 2015 12:42 pm

Blockchain initiative backed by 9 large investment banks

Philip Stafford

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Nine of the largest investment banks, including Goldman Sachs, JPMorgan and Credit Suisse, are planning to develop common standards for blockchain technology in an effort to broaden its use across financial services.

The group is looking to channel data, ideas and financial backing to a start-up called R3CEV, a New York-based group of trading and technology executives.

In the news….

R3CEV includes:

- $600b market cap
- 60% are Global SIFIs

In the news….

May 11, 2015 6:43 pm

Nasdaq adopts bitcoin backbone for stocks

Richard Waters in San Francisco

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Nasdaq is to start using the technology behind the virtual currency bitcoin to handle transactions on its market, making it what is thought to be the first major financial market to adopt the idea.

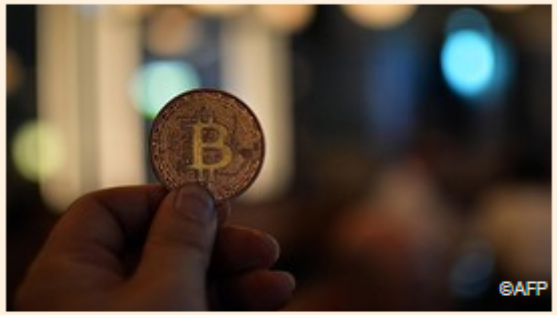
The blockchain — the backbone on which bitcoin depends — has attracted wide interest in the financial world as a potentially revolutionary way to streamline many different types of transactions, though few alternative applications have yet been tried beyond bitcoin.

In the news….

April 30, 2015 4:00 am

Goldman backs fundraising by payments company Circle

Stephen Foley in New York Author alerts



Goldman Sachs is backing the latest fundraising by Circle Internet Financial, a mobile payments start-up built on the bitcoin network.

Boston-based Circle has announced a $50m cash infusion, led by Goldman and China-focused venture capital firm IDG Capital Partners, to help fund its expansion beyond bitcoin and into other currencies.

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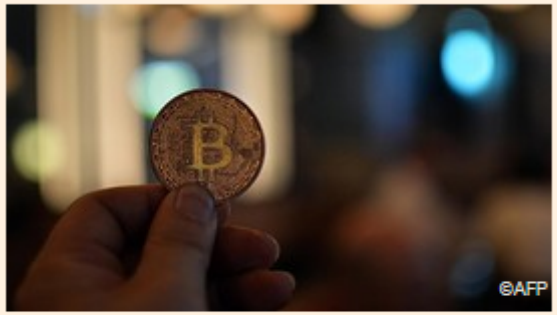

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January 20, 2015 8:05 pm

Bitcoin company Coinbase lands $75m investment from NYSE and BBVA

Sally Davies in London and Thomas Hale in Madrid Author alerts

Coinbase has become the world's most well-funded bitcoin company after landing a $75m investment from high-profile backers, including the New York Stock Exchange, Spanish bank BBVA and the former chief executives of Citigroup and Reuters respectively.

The funding round in the San Francisco-based start-up that lets people store, send and accept payment in bitcoins, was led by DFJ, the venture capital group. But it is the presence of traditional financial services companies and figures which will be interpreted as an indicator of growing investor interest in mainstream applications of the controversial digital currency.

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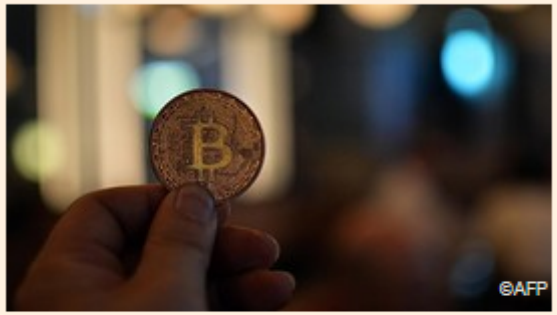

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March 10, 2015 11:02 pm

Masters joins cryptocurrency start-up

Tom Braithwaite and Ben McLannahan in New York Author alerts

Blythe Masters, the former JPMorgan executive who helped pioneer credit derivatives in the 1990s, has re-emerged as chief executive of a cryptocurrency start-up.

Digital Asset Holdings aims to be a venue for buyers and sellers of financial assets to meet and transact, switching currencies into bitcoin in order to cut the cost and time of settlement and make use of the decentralised "block chain" as a secure record of transactions.

Campbell R. Harvey 2016

Original blockchain

Let's start with the bitcoin blockchain:

- A distributed, secure, transparent, public ledger that establishes ownership and allows for the efficient exchange of ownership
- Available to anyone for download on the Internet (decentralized)
- Does not depend on trust (controlled by no one – monitored by everyone)
- Backed by strong cryptography secured by the world's most powerful network of computers
- Miners provide security and are rewarded with new cryptocurrency

Original blockchain

How powerful?

- Currently 20,507,779 petaFLOPS
- #1 supercomputer is Sunway TaihuLight at 93 PetaFLOPS
- Sum of top 500 is only 593 petaFLOPS
- Blockchain uses specialized hardware and floating point operations are not needed. Cost of 50% of the network power is about $1 billion

Campbell R. Harvey 2016

http://bitcoincharts.com/bitcoin/ http://www.top500.org/ https://www.top500.org/statistics/perfdevel/ (20 zettaFLOPS)

Hashing 101

A simple hash

Suppose I send an email to Luke. However, he needs to verify that what I sent him is exactly what he received.

- Email contains a single word “hello”.
- Encode the word (a=1, b=2, …, z=26), so 8 5 12 12 15.
- Multiply the numbers to get 86,400.
- I post the hash on my website. After Luke gets my email, he does the same hash and checks my website.
- If the message was corrupted the hash will not match, for example, “hallo”= 8x1x12x12x15=17,280 which does not match the original.
- This hash is too simple (e.g. hello=ohell)

Hashing 101

SHA-256 (Secure Hashing Algorithm)

http://www.xorbin.com/tools/sha256-hash-calculator

Hashing is a one-way function.

For example, passwords are routinely stored on websites in hashed form.

The output of a SHA-256 is 256 bits no matter how big the input

Let's do some examples:

Hashing 101

SHA-256 (Secure Hashing Algorithm)

http://www.xorbin.com/tools/sha256-hash-calculator

Let's hash the phrase: "Hello, world!" with a special number appended. No spaces. Do it three times for three different strings.

Hello, world!0

Hello, world!1

Hello, world!4250

Hashing 101

SHA-256 (Secure Hashing Algorithm)

- King James Bible (4.2mb)
  47f63b8cd8470051acd3a3c0bd5c77c4aa9574d79cf5bfb3e576facabbc11491

- King James Bible (4.2mb) – with 5 characters deleted
  961c112581bd04e67285f56a354c98ad56cd65244dc768545cfde5bd8ef639c1

Note: You can hash the hashes

- King James Bible SHA-256 of SHA-256
  0c8b120036a32525e9737fa8ed67b9af337affc7dae557d7244592c286b2cfd8

Hashing 101

The only way to break a hash is brute force:

- Need $2^{255} = 1.15*10^{77}$ guesses
- Which is roughly the number of atoms* in the known universe!

*Number of atoms between 10^{78} to 10^{82} http://www.universetoday.com/36302/atoms-in-the-universe/

Hashing 101

SHA-256 hashes widely used for email and file transfer

- Returning to the email example, I want to send a file to Louise
- I SHA-256 the file
- I send Louise the original file
- Louise does her own SHA-256 hash of the file
- Louise checks to see if her hash of the file matches the hash that I have on my website
- If there is any difference, the file has been corrupted
- This all happens automatically and is called “checksum”

How does the bitcoin blockchain work?

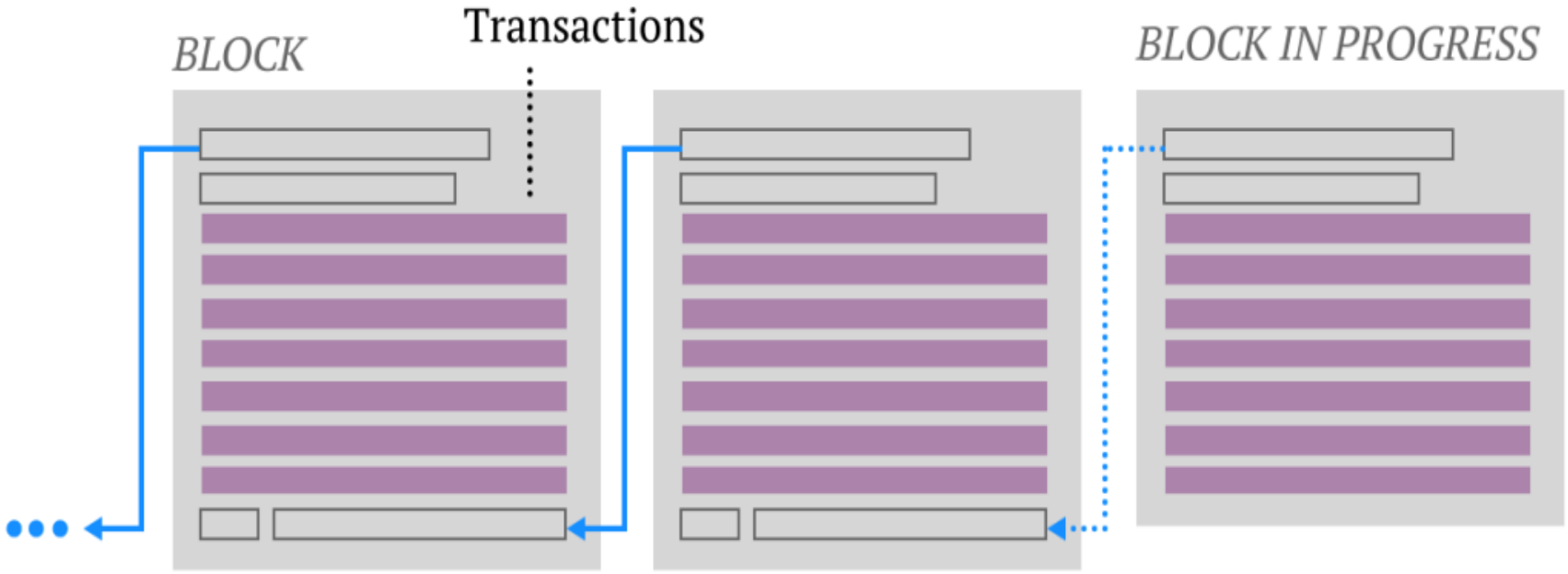
Every transaction ever made on the blockchain is public

- Ledger is append-only and immutable
- Serves as a basis of trust
- Can store (limited) metadata as well as transactions

How does the bitcoin blockchain work?

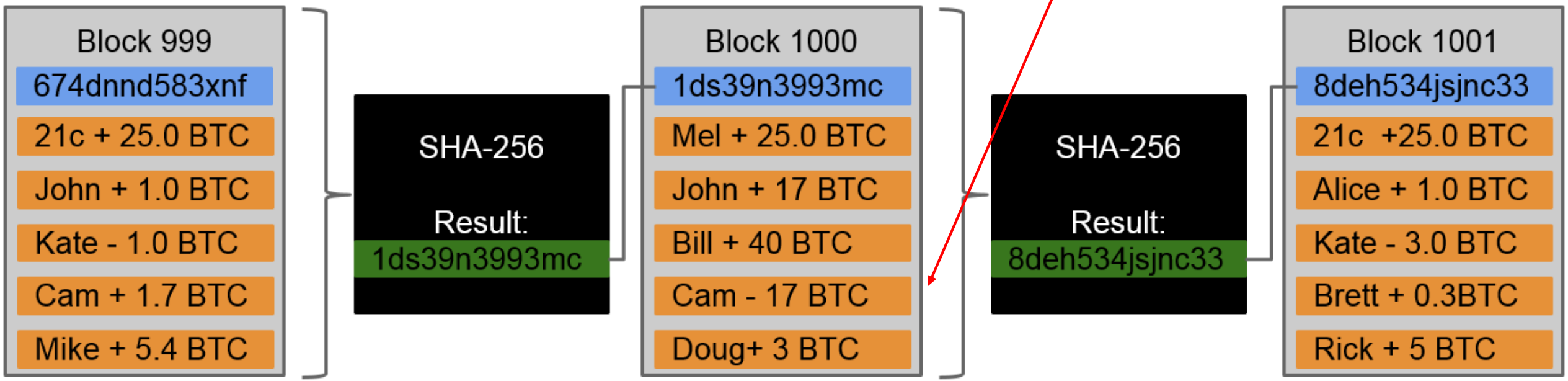
Ledger broken up into 10 minute “blocks”

- Every block contains a hashed reference to the block before it so you can trace every transaction all the way back to 2009



How does the bitcoin blockchain work?

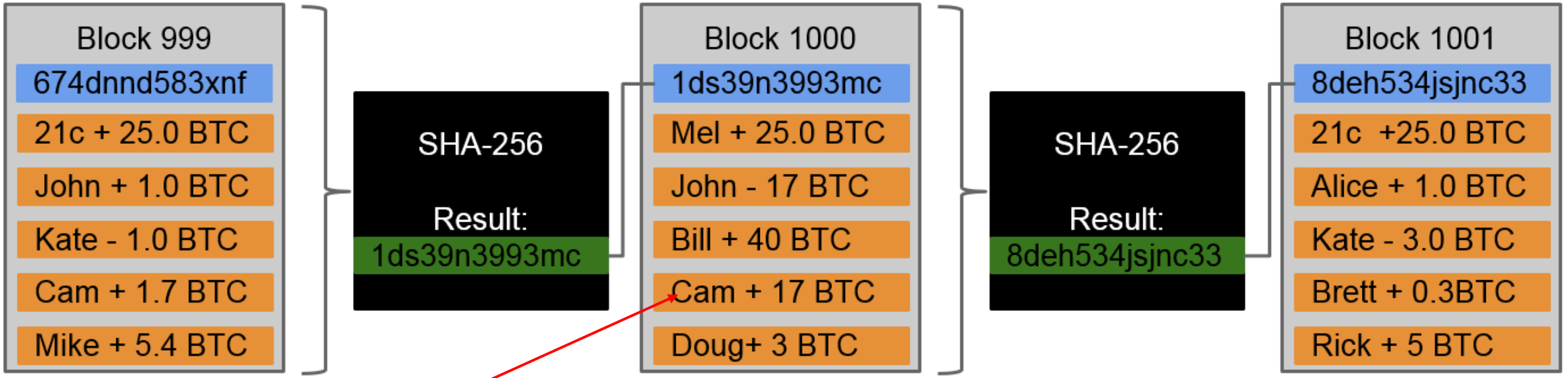
Example. In block 1000, I buy a car (for 17 BTC) from John



How does the bitcoin blockchain work?

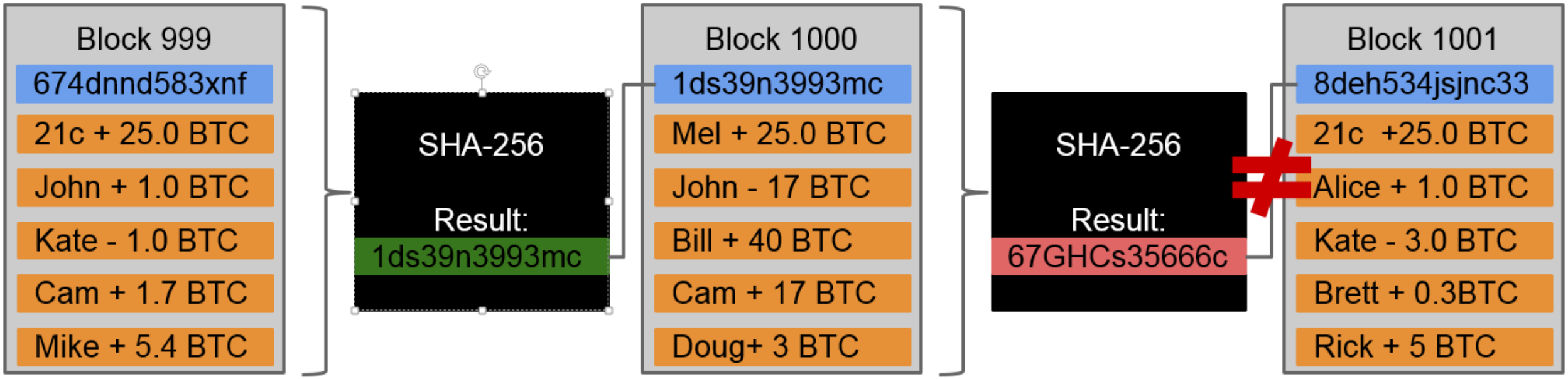
Suppose I edit the block on my computer – to give me 17 BTC!

I then broadcast to the network



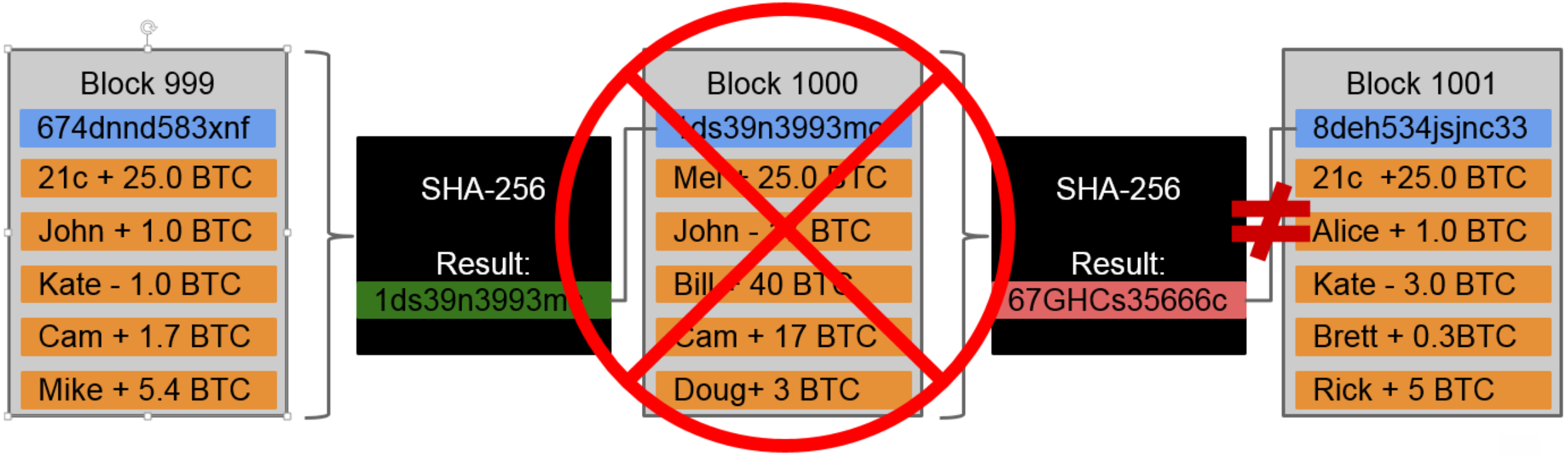
How does the bitcoin blockchain work?

Even making that small change results in a very different block hash. It no longer matches what is stored in block 1001.



How does the bitcoin blockchain work?

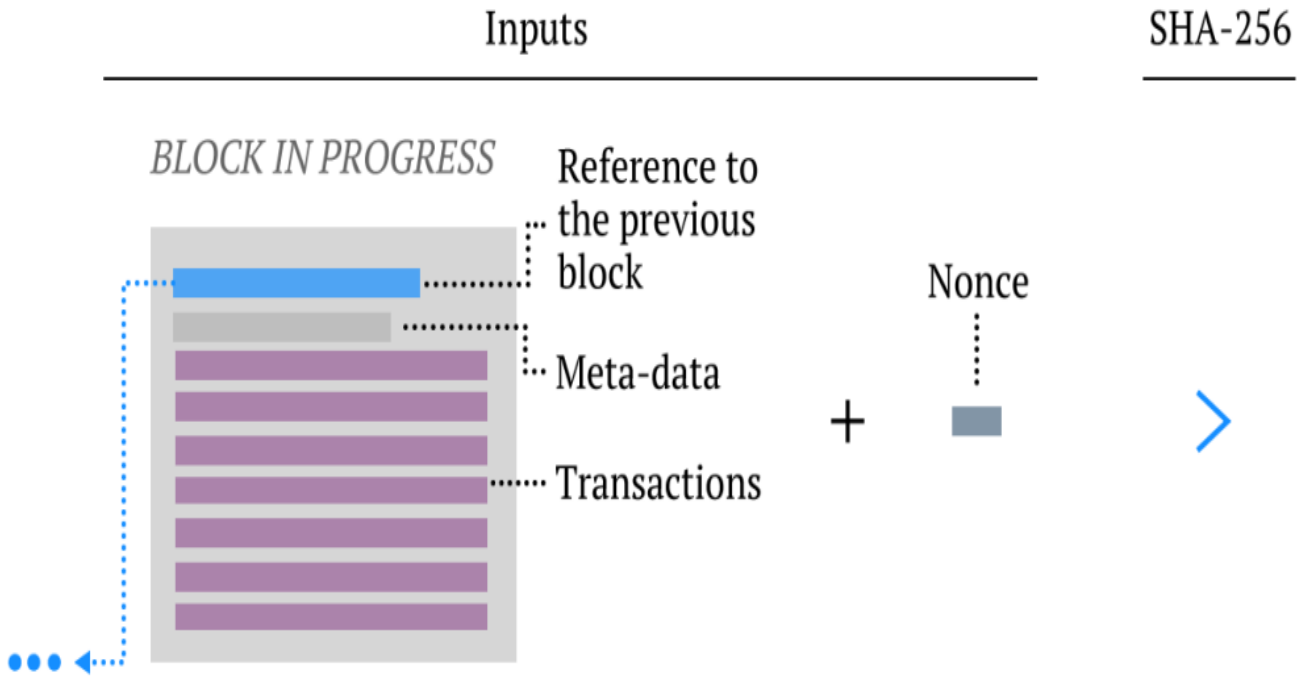
Blockchain clients automatically compute the hash themselves - if no match, they reject the block - Check other peers in the network for correct block



How does the bitcoin blockchain work?

But there is more to it! Here is where the miners come in.

- Miners group the current transactions together and take a hash of the transactions plus a “magic number” – called a “nonce”.



How does the bitcoin blockchain work?

But there is more to it! Here is where the miners come in.

- Miners try different nonces to get a special hash that has a certain number of leading zeros
- More leading zeroes means fewer solutions – and more time to solve the problem
- Think of shuffling 5 decks of cards. You goal is to turn over 5 aces of spades in the first five cards! That will be a lot of shuffling.

How does the bitcoin blockchain work?

But there is more to it! Here is where the miners come in.

- Current difficulty is 17 leading zeros! Probability = $(1/16)^{17}$
- Odds of winning two Powerball jackpots* in a row approx $(1/16)^{15}$
- Someone finds the winning hash approximately every 10 minutes
- This means 1 billion gigahashs calculated every second
- System is immune to increases in computing speed – the difficulty automatically adjusts if the hash is found in less than 10 minutes

*One Powerball = 3.4223E-09; two Powerballs in a row = 1.17122E-17; 17 zeroes in winning hash 3.3888E-21; 18 zeros 2.117E-22

How does the bitcoin blockchain work?

But there is more to it! Here is where the miners come in.

- It is easy to verify the hash is correct
- Anyone can take the hash of the transactions + nonce and get the hash with the 17 leading zeros
- However, any change in any transaction – no matter how trivial – will lead to a completely different hash (and unlikely to have any leading zeros)
- Miners are rewarded with cryptocurrency for finding the winning hash and verifying transactions. There are also small transaction fees.

Distributed public ledger

Bitcoin blockchain:

- Anyone can write to ledger and anyone can mine, i.e. no “censorship”
- Network determines “settlement”
- Having extreme “difficulty” is expensive (power consumption) but reduces or eliminates the possibility of any single person (or miners) from doing anything nefarious.

Permissioned blockchains

What not just operate on consensus?

- Consensus may be problematic if the blockchain is open because someone could take over millions of computers and impose their will (Sybil attack)
- However, significant advances have been made by firms like Ethereum to refine the consensus method and eliminate the Sybil attack risk

HOME SEARCH

The New York Times

Ethereum, a Virtual Currency, Enables Transactions That Rival Bitcoin's

The Race Is On to Control Artificial Intelligence, and Tech's Future

FAIR GAME
In Yahoo, Another Example of the Buyback Mirage

DEAL PROFESSOR
Challenge to Yahoo's Board Makes a Sale More Certain

DealB%k WITH FOUNDER ANDREW ROSS SORKIN

Ethereum, a Virtual Currency, Enables Transactions That Rival Bitcoin's

By NATHANIEL POPPER MARCH 27, 2016

Private blockchains

This is where permissioned blockchains enter

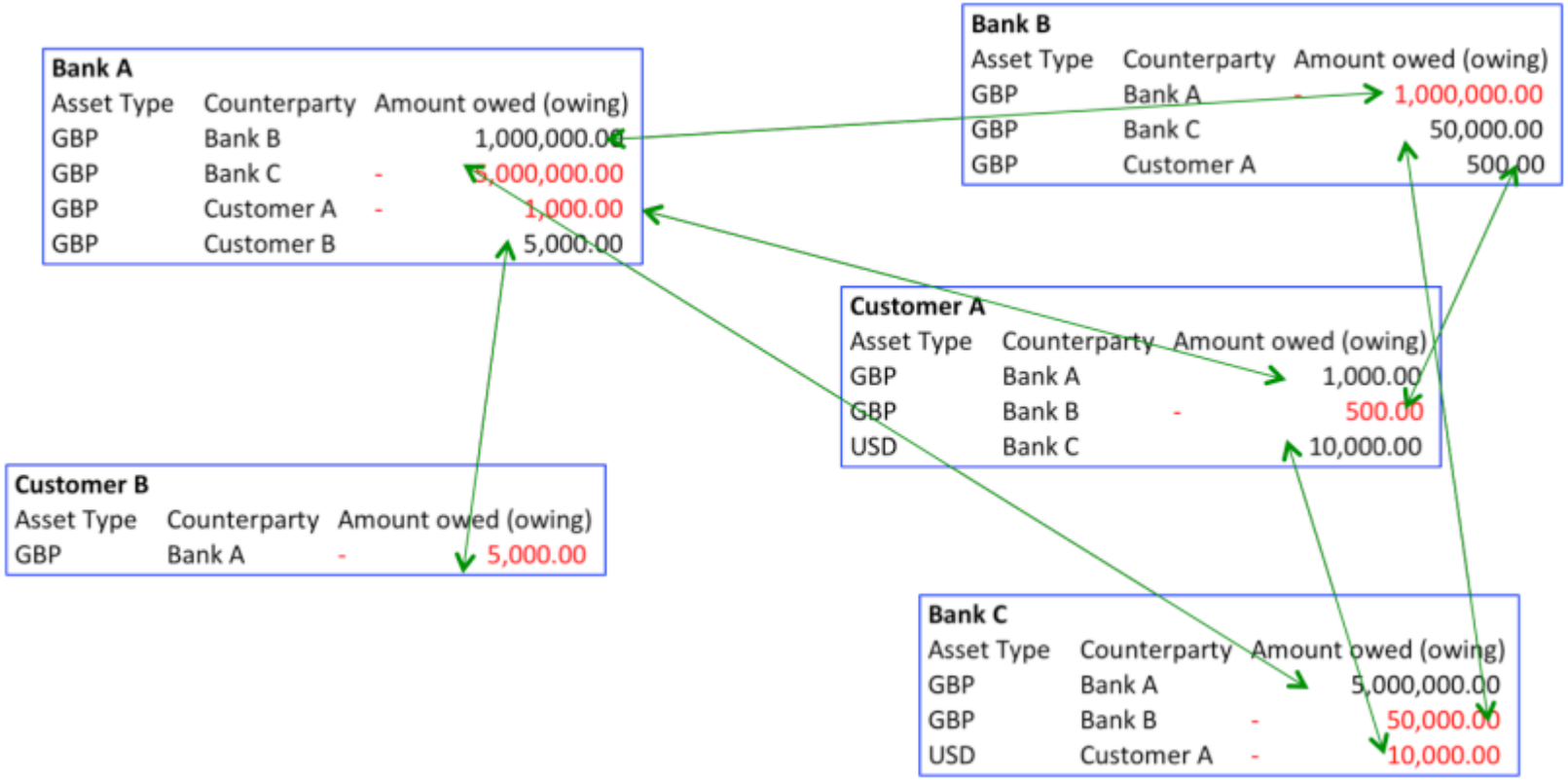
- All major banks are now in this space (e.g. R3CEV and DAH-Hyperledger)
- Currently, bank accounting systems are inefficient where each bank has its own independent ledger
- Having a unified but distributed ledger is very attractive: obvious cost savings on technology, instant transactions across banks, reduced need for branches, heightened security
  - Global bank IT spending in 2015 estimated at $196 billion (Celente)*
  - Distributed ledger could save $15-$20 billion per year (Santander)**

* http://www.finextra.com/news/fullstory.aspx?newsitemid=26979

** http://www.finextra.com/finextra-downloads/newsdocs/The%20Fintech%202%200%20Paper.PDF

Private blockchains

Example: 3 banks, 2 customers



http://gendal.me/2015/04/27/how-to-explain-the-value-of-replicated-shared-ledgers-from-first-principles/

Private blockchains

Example: 3 banks, 2 customers + 1 blockchain

Bank A		
Asset Type	Counterparty	Amount owed (owing)
GBP	Bank B	1,000,000.00
GBP	Bank C	-5,000,000.00
GBP	Customer A	-1,000.00
GBP	Customer B	5,000.00

Bank B		
Asset Type	Counterparty	Amount owed (owing)
GBP	Bank A	-1,000,000.00
GBP	Bank C	50,000.00
GBP	Customer A	500.00

Bank C		
Asset Type	Counterparty	Amount owed (owing)
GBP	Bank A	5,000,000.00
GBP	Bank B	-50,000.00
USD	Customer A	-10,000.00

Customer A		
Asset Type	Counterparty	Amount owed (owing)
GBP	Bank A	1,000.00
GBP	Bank B	-500.00
USD	Bank C	10,000.00

Customer B		
Asset Type	Counterparty	Amount owed (owing)
GBP	Bank A	-5,000.00

Issuer	**Holder**	**Asset**	**Amount**
Bank A	Bank C	GBP	5,000,000.00
Bank A	Customer A	GBP	1,000.00
Bank B	Bank A	GBP	1,000,000.00
Bank C	Bank B	GBP	50,000.00
Bank C	Customer A	USD	10,000.00
Customer A	Bank B	GBP	500.00
Customer B	Bank A	GBP	5,000.00

Campbell R. Harvey 2016

http://gendal.me/2015/04/27/how-to-explain-the-value-of-replicated-shared-ledgers-from-first-principles/

Private blockchains

Private blockchains restrict who can verify

- For example, only banks are allowed to verify transactions and only banks are allowed to write to their blockchain
- Their contribution to the computing capacity is by contract
- This system imposes “censorship” – but, importantly, there is no obvious need for censorship-resistance
- In this case, there is not even a need for a cryptocurrency

Permissioned blockchains

Private blockchains advantages

- No need for cryptocurrency to pay miners
- Less (or no) mining necessary and lower power consumption
- Common accounting system benefit for banks
- Clear governance
- No limit on the number of transactions (currently the bitcoin blockchain can only handle 7 transactions a second – and scalability is an issue)
- Faster blocks (could be every few seconds not 10 minutes)
- Specialized ledgers (multiple blockchains) for other types of contracts
- Blockchain greatly eases the job of the regulator who has the ability to see all transactions – and the identities of the transactors

Permissioned blockchains

Private blockchains disadvantages

- Are they as secure as bitcoin blockchain? Potential issues with banks holding private keys and veryifying their own transactions.
- Centralized rather than decentralized (you need to rely on the banks and banks will do what is in their best interests)
- Reliant on central bank currencies (which is not a big deal in the U.S., but is in many other countries)
- Blockchain vs. database debate: All blockchains are distributed ledgers but not all distributed ledgers are blockchains.

Private blockchains

Can the different types of chains be connected?

- Yes.
- A sidechain is a “blockchain that validates data from other blockchains”
- It is possible to run a permissioned sidechain that is “pegged” to the bitcoin blockchain. This is the idea of Blockstream’s Liquid.*

*https://blockstream.com/2015/11/02/liquid-recap-and-faq/ and https://blockstream.com/sidechains.pdf

Blockchain applications

Voting

- Each citizen registered is issued a voting token
- The token cannot be sold and it can be used only once
- It expires after the election
- Voter needs to provide proof of identity (thumb print) to vote
- Blockchain is checked to see if that voter has the token to “spend”
- Your vote can be anonymous even though you provide proof of identity with “zero knowledge proof”

https://crypto.stanford.edu/pbc/notes/crypto/voting.html

Blockchain applications

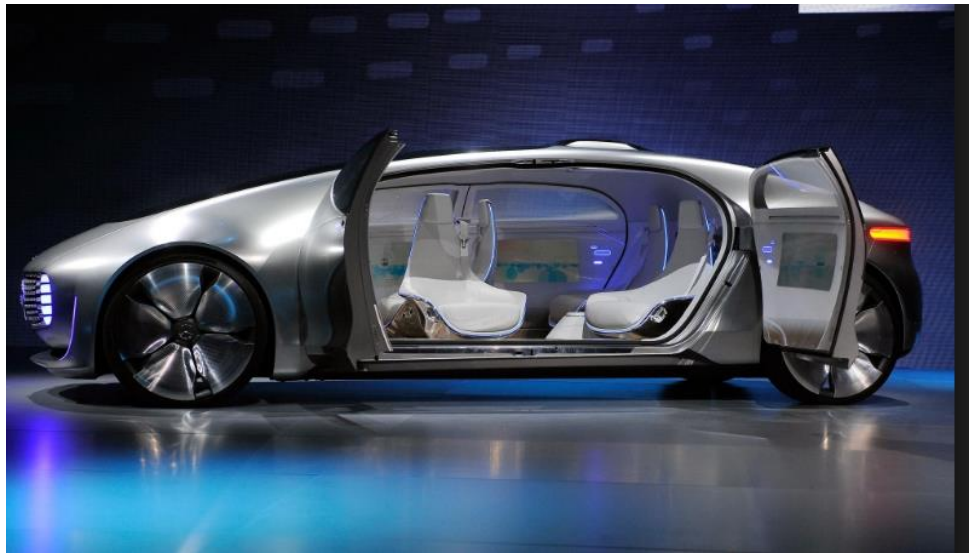
Internet of Things

- Only you can control your thermostat
- Provide proof of identity (blockchain is checked) and IoT device works for you
- Strong protection against hacking because the hacker would have to rewrite the entire blockchain and take over the majority of computing

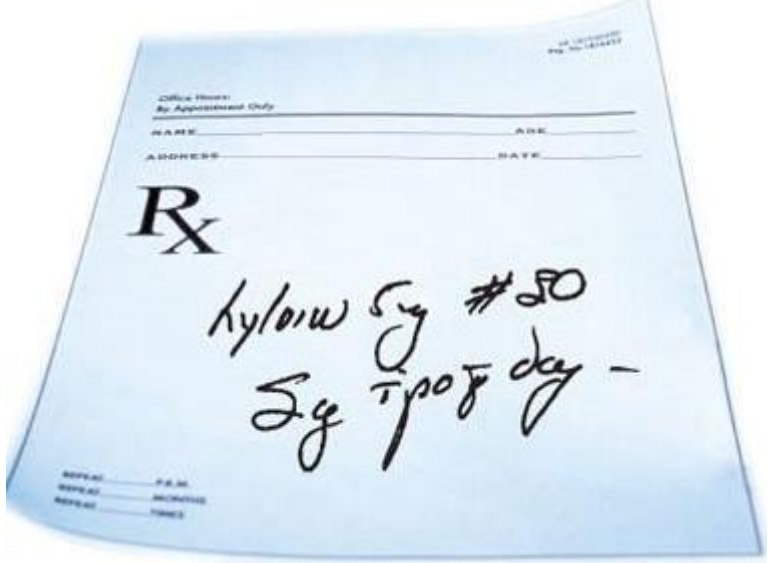
Blockchain applications

Internet of Things

- Only you can control your car
- Provide proof of identity (blockchain is checked) and IoT device works for you
- Driverless cars are a “no go” unless they are hack proof.



Blockchain applications



Prescriptions

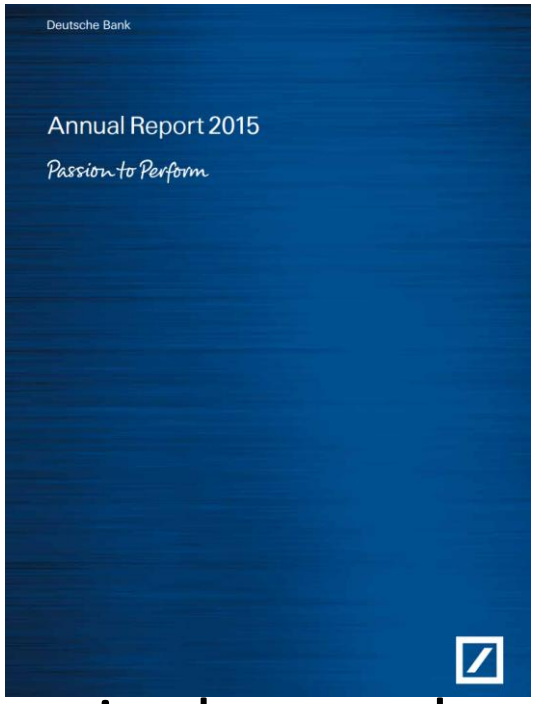
- Widespread fraud
- Blank scripts are stolen from doctors' offices or forged
- Some doctors abuse the system
- Token issued to patient: it cannot be resold and has an expiration
- Patient presents token to pharamacist and blockchain is checked to make sure patient owns the token (and has not already spent it)

Blockchain applications

Medical records

- You enter a health facility (not your home facility)
- You provide proof of identity verified with a blockchain
- Your “private key” unlocks encrypted data related only your health records
- Also provides a much stronger privacy protection
  - Instead of a medical database being encrypted with one key (which might be lost or discovered), each patient’s record has its own key. Hence, to compromise the database you would need to guess potentially millions of keys

Blockchain applications



Real time financial statements

- New role for Deloitte, E&Y, PwC, etc. in validating company ledger transactions in real time
- API would allow selected transparency (same categories as in the usual financial statements) in real time
- The end of quarterly reporting – and potentially some of the incentives that are created to engage in short-termism

Blockchain applications

Fedcoin

- 78% of the value of US currency is in $100 bills
- Large denomination bills method of choice for criminal activity

Blockchain applications

Fedcoin

- 78% of the value of US currency is in $100 bills
- Large denomination bills method of choice for criminal activity
- Fedcoin is a digital USD currency where the complete history of all transactions is visible to the Fed via a Fed blockchain
- Instant monetary policy, see Rogoff (2016)

El Chappo's cash stash

Blockchain applications

Central banks

FINANCIAL TIMES

Canada experiments with digital dollar on blockchain

Philip Stafford

The Telegraph

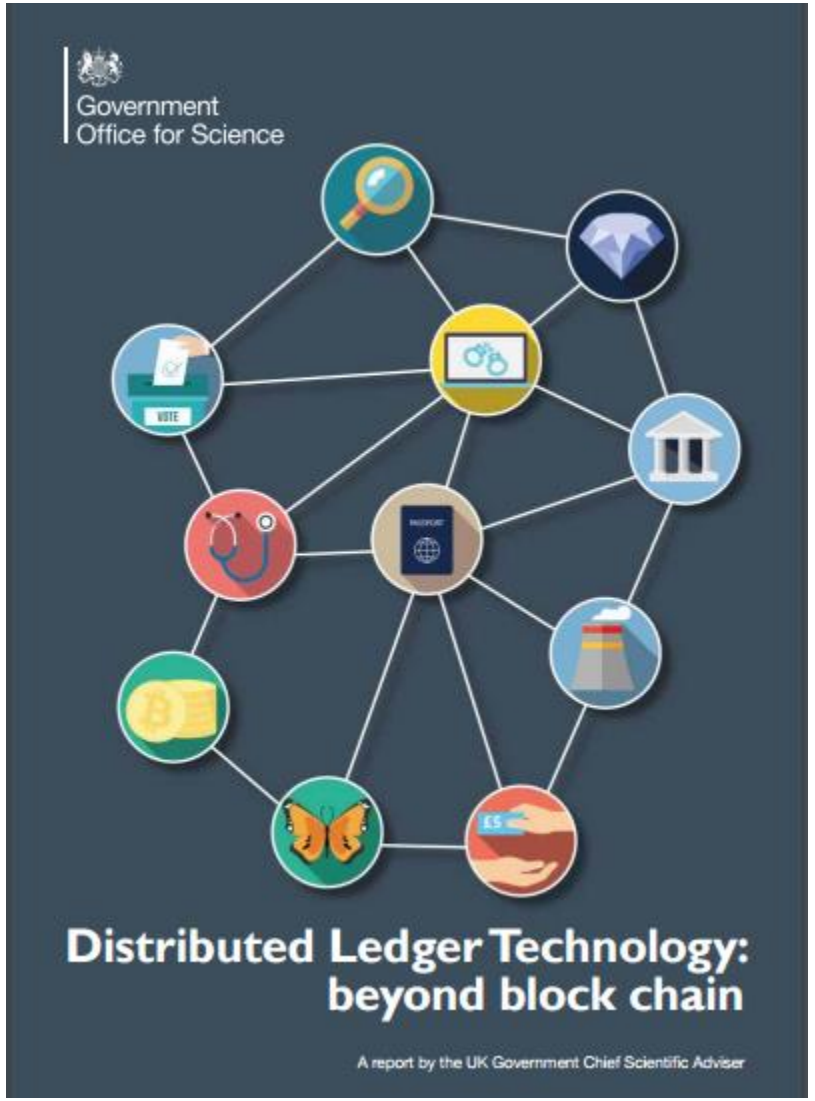
HOME | NEWS | SPORT

Business

Economy | Companies | Opinion | Markets | A-Z | Alex | Telegraph Connect | Events

Business

Central banks beat Bitcoin at own game with rival supercurrency



Conclusions

Blockchain will first disrupt financial services

- Still early going but change will happen quickly
- Low hanging fruit in financial applications
- Next applications based on other types of property like real estate, digital media,…
- Blockchain may be crucial to IoT applications that are at risk from hacking In the short-term, I see the growth of a diverse set of blockchain types
- Bitcoin blockchain is the strongest – but many applications do not require censorship resistance; sidechains offer interesting opportunities
- Alternative blockchains such as the one proposed by Ethereum allow for simple contracts to be embedded in the blockchain and offer great promise
- Blockchain not going away