

# Overview of Bitcoin, Blockchain, and Cryptofinancial Technology

Ryan X. Charles  
Blockchain University  
Tokyo, Dec. 17, 2015



Ryan X. Charles  
Founder of Datt ([datt.co](http://datt.co))  
[twitter.com/ryanxcharles](https://twitter.com/ryanxcharles)  
[github.com/ryanxcharles](https://github.com/ryanxcharles)

Code Samples and Slides at:  
[github.com/ryanxcharles/blockchain-university](https://github.com/ryanxcharles/blockchain-university)



# Outline

Who am I?

Bitcoin History & Technology

Altcoins & Other Blockchains

Non-Blockchains

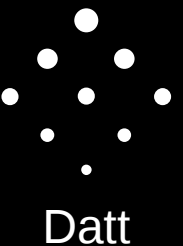
Bitcoin Economy

Bitcoin Implementations



Ryan X. Charles  
Founder of Datt ([datt.co](http://datt.co))  
[twitter.com/ryanxcharles](https://twitter.com/ryanxcharles)  
[github.com/ryanxcharles](https://github.com/ryanxcharles)

Code Samples and Slides at:  
[github.com/ryanxcharles/blockchain-university](https://github.com/ryanxcharles/blockchain-university)



# Who is Ryan X. Charles?

- Programming since age 10
- Web designer/developer, 1999 – 2005
- Physicist, 2005 – 2013
- Angry at govt/banks, 2008
- Discovered bitcoin, 2011
- Full-time bitcoin, 2013
- BitPay -> reddit -> BitGo -> Datt
- bitcore, Copay, fullnode, Datt



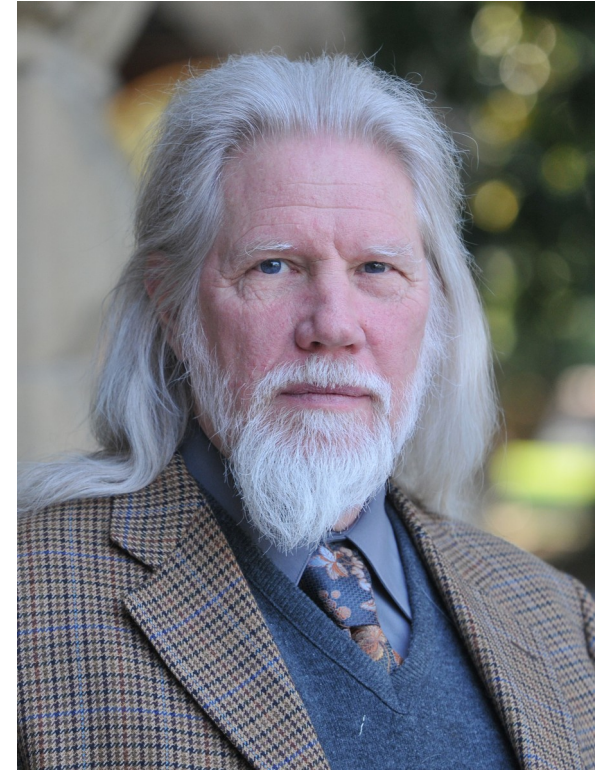
Ryan X. Charles  
Founder of Datt ([datt.co](http://datt.co))  
[twitter.com/ryanxcharles](https://twitter.com/ryanxcharles)  
[github.com/ryanxcharles](https://github.com/ryanxcharles)

Code Samples and Slides at:  
[github.com/ryanxcharles/blockchain-university](https://github.com/ryanxcharles/blockchain-university)



# Crypto History of Bitcoin

- Public Key Cryptography, 1976 (Diffie-Hellman)
- DigiCash, 1990 – 1998
- Hashcash, Adam Back, 1997
- b-money, Wei Dai 1998
- Bit Gold, Nick Szabo, 2005? 2008?
- Bitcoin Whitepaper, 2008
- Bitcoin Genesis Block, 2009

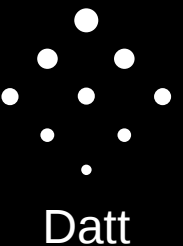


Whitfield Diffie



Ryan X. Charles  
Founder of Datt ([datt.co](http://datt.co))  
[twitter.com/ryanxcharles](https://twitter.com/ryanxcharles)  
[github.com/ryanxcharles](https://github.com/ryanxcharles)

Code Samples and Slides at:  
[github.com/ryanxcharles/blockchain-university](https://github.com/ryanxcharles/blockchain-university)



# Money History of Bitcoin

- Pre-gold\*, ~100,000 BC – Today
- Gold\*, ~5000 BC
- Fractional Reserve Banking\*, ~1000 AD
- Classical Gold Standard, 1870 – ~1915
- Bretton Woods, 1944 – 1971
- Bitcoin, 2009

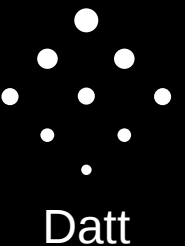


\* Caveat: Rough estimate



Ryan X. Charles  
Founder of Datt ([datt.co](http://datt.co))  
[twitter.com/ryanxcharles](https://twitter.com/ryanxcharles)  
[github.com/ryanxcharles](https://github.com/ryanxcharles)


Code Samples and Slides at:  
[github.com/ryanxcharles/blockchain-university](https://github.com/ryanxcharles/blockchain-university)





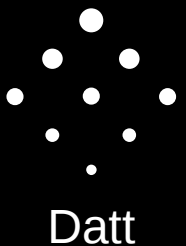
# Rai Stones: Physical Bitcoin

- Quarried in Micronesia & Guam
- Used as money on Yap
- Stones do not move – rely on oral history to track ownership
- Really difficult to make new ones – can't just print them (without modern tech)
- Just like bitcoin: value comes from proof-of-work, history of ownership is shared information



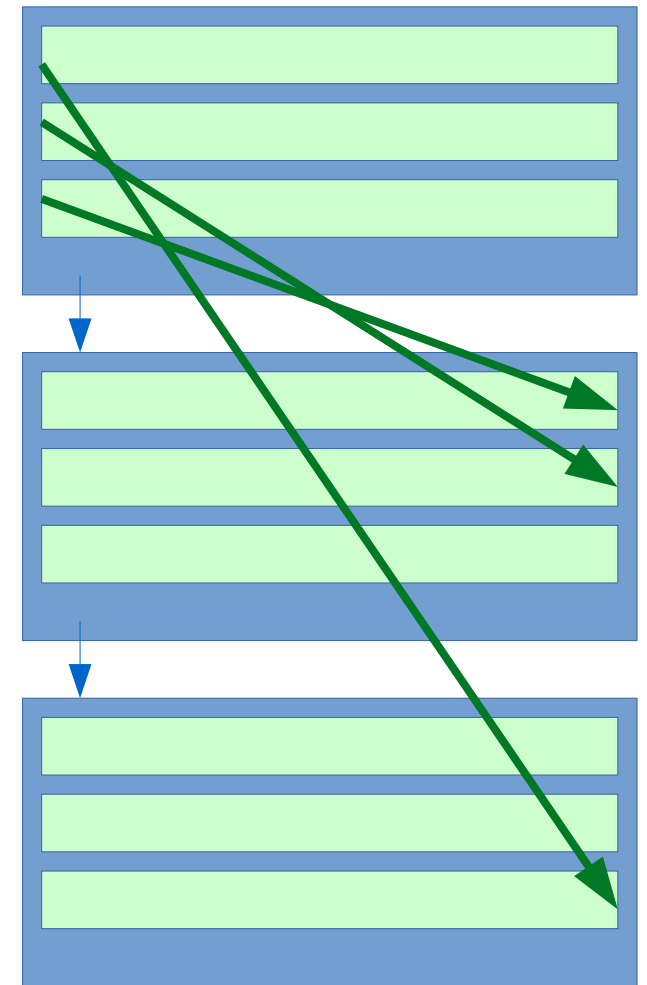
Ryan X. Charles  
Founder of Datt ([datt.co](https://datt.co))  
[twitter.com/ryanxcharles](https://twitter.com/ryanxcharles)  
[github.com/ryanxcharles](https://github.com/ryanxcharles)

Code Samples and Slides at:  
[github.com/ryanxcharles/blockchain-university](https://github.com/ryanxcharles/blockchain-university)



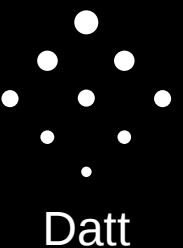
# Bitcoin Blockchain Overview

- Blocks contain transactions and a proof-of-work hash
- Each block links to previous block
- Each transaction links to outputs of earlier transactions



Ryan X. Charles  
Founder of Datt ([datt.co](http://datt.co))  
[twitter.com/ryanxcharles](https://twitter.com/ryanxcharles)  
[github.com/ryanxcharles](https://github.com/ryanxcharles)

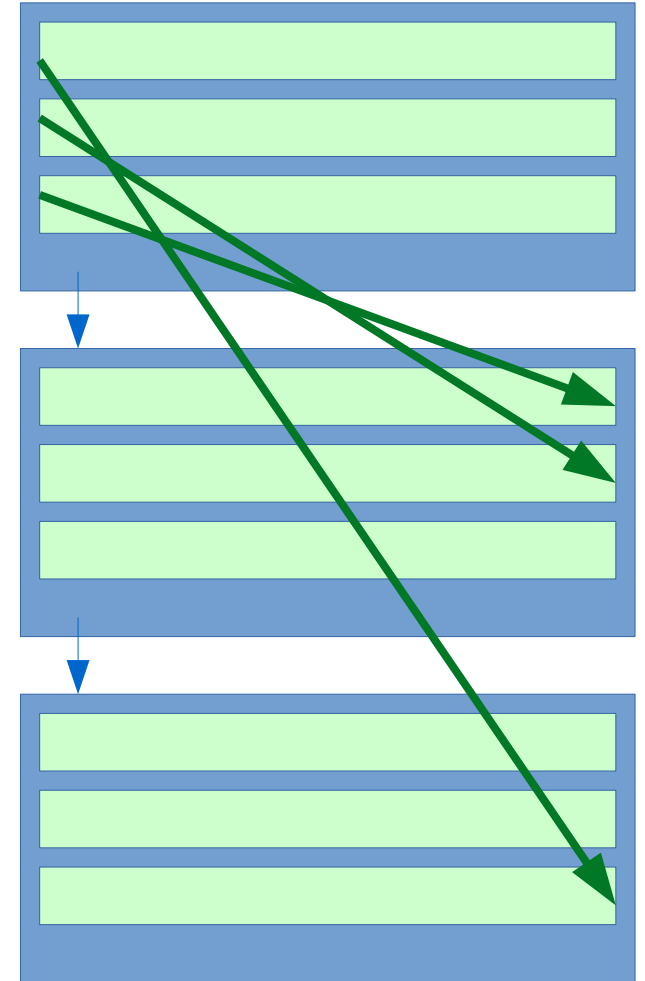
Code Samples and Slides at:  
[github.com/ryanxcharles/blockchain-university](https://github.com/ryanxcharles/blockchain-university)



Datt

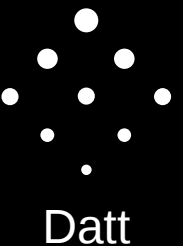
# Bitcoin Blockchain Overview

- Genesis Block:
  - The First Block
- Coinbase Transaction:
  - First transaction in a block
  - Mining reward
  - Has “null” inputs



Ryan X. Charles  
Founder of Datt (datt.co)  
[twitter.com/ryanxcharles](https://twitter.com/ryanxcharles)  
[github.com/ryanxcharles](https://github.com/ryanxcharles)

Code Samples and Slides at:  
[github.com/ryanxcharles/blockchain-university](https://github.com/ryanxcharles/blockchain-university)





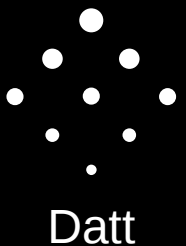
# Bitcoin Blockchain Overview

- Each block has:
  - Proof-of-Work Hash (PoW)
  - Nonce
  - Meta data and transactions
- Example PoW with data “test data”
  - Nonce: 0, Hash: `df59bb7272f144dc7d3620e6f9e14234`
  - Nonce: 1, Hash: `460142d2a0349c13a48b422261d708eb`
  - Nonce: 2, Hash: `71be158053f58c9e1f094fb3f7da282e`
  - ...
  - Nonce: 146, Hash: `00f82186722b46b2adb57f321793e44f`



Ryan X. Charles  
Founder of Datt ([datt.co](https://datt.co))  
[twitter.com/ryanxcharles](https://twitter.com/ryanxcharles)  
[github.com/ryanxcharles](https://github.com/ryanxcharles)

Code Samples and Slides at:  
[github.com/ryanxcharles/blockchain-university](https://github.com/ryanxcharles/blockchain-university)



Datt

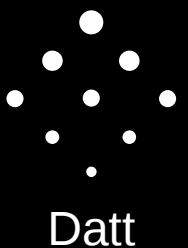
# Bitcoin Blockchain Summary

- Transactions are digitally signed (public key cryptography).
  - Cannot fake a transaction – must have private key to produce valid signature
- Hash functions used for proof-of-work on each block.
- “Encryption” has nothing to do with it – just digital signatures and hash functions.
- Transactions grouped in blocks, one big chain back to the genesis block.
- Each transaction links to earlier transaction(s) back to Coinbase transaction(s).



Ryan X. Charles  
Founder of Datt ([datt.co](http://datt.co))  
[twitter.com/ryanxcharles](https://twitter.com/ryanxcharles)  
[github.com/ryanxcharles](https://github.com/ryanxcharles)

Code Samples and Slides at:  
[github.com/ryanxcharles/blockchain-university](https://github.com/ryanxcharles/blockchain-university)



# Important Concepts

- Bitcoins are mined. 50 new bitcoins per block for first four years, 25 per block for next four years, etc. Total of 21 million.
- Miners perform proof-of-work hashing. CPUs → Graphics cards → FPGAs → ASICs.
- “full node” - a fully-validating node. “light node”, or “SPV” - only validates block headers.
- **Bitcoin has no central authority.** The only way to change the rules is to change the software the miners, full nodes, and wallets run. Democratic by CPU power and economic power.
- Do you control your private keys?



Ryan X. Charles  
Founder of Datt ([datt.co](http://datt.co))  
[twitter.com/ryanxcharles](https://twitter.com/ryanxcharles)  
[github.com/ryanxcharles](https://github.com/ryanxcharles)

Code Samples and Slides at:  
[github.com/ryanxcharles/blockchain-university](https://github.com/ryanxcharles/blockchain-university)



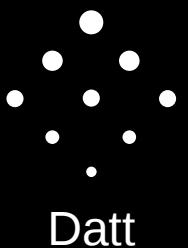
# The Creator: Satoshi Nakamoto

- Active on cryptography mailing list 2008
- Active on bitcoin forum 2009 – 2010
- Last known message late 2010
- Writings recorded at:  
<http://nakamotoinstitute.org/>
- Highly recommended to read his writings!



Ryan X. Charles  
Founder of Datt (datt.co)  
twitter.com/ryanxcharles  
github.com/ryanxcharles

Code Samples and Slides at:  
[github.com/ryanxcharles/blockchain-university](https://github.com/ryanxcharles/blockchain-university)



# Byzantine Consensus

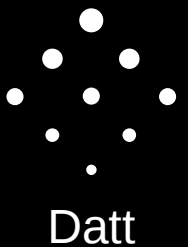
- **Byzantine Generals Problem** – a well-known computer science problem.
- If generals want to attack a city, when no one is in charge, how do they arrive at consensus about what particular time to attack?
- **Bitcoin is a solution to this problem** (use proof-of-work on times – most proof-of-work wins)

<https://bitcointalk.org/oldSiteFiles/byzantine.html>



Ryan X. Charles  
Founder of Datt (datt.co)  
twitter.com/ryanxcharles  
github.com/ryanxcharles

Code Samples and Slides at:  
[github.com/ryanxcharles/blockchain-university](https://github.com/ryanxcharles/blockchain-university)



# “The Blockchain”

- **“Bitcoin: A Peer-to-Peer Electronic Cash System”**

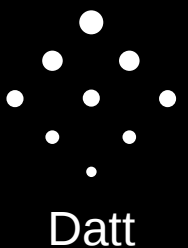
<https://bitcoin.org/bitcoin.pdf>

- The word “blockchain” does not appear in whitepaper or original source code. (“block chain”, two separate words, does appear in original source code, but not whitepaper)
- “Blockchains,” distributed consensus of transactions grouped into blocks, have become popular for reasons other than money, particularly other financial services & identity.
- Bitcoin was invented for one purpose: decentralized electronic cash. Other uses of blockchain are nice bonus.



Ryan X. Charles  
Founder of Datt (datt.co)  
[twitter.com/ryanxcharles](https://twitter.com/ryanxcharles)  
[github.com/ryanxcharles](https://github.com/ryanxcharles)

Code Samples and Slides at:  
[github.com/ryanxcharles/blockchain-university](https://github.com/ryanxcharles/blockchain-university)





# Altcoins

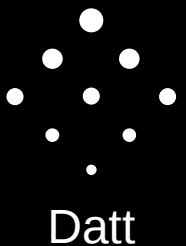
## (The First Non-Bitcoin Blockchains)

- First appeared ~2012.
- Litecoin first popular altcoin.
- Dogecoin second popular altcoin.
- Almost all are forks of bitcoin, or a fork of a fork. Some, like NXT, are complete rewrites.
- Most do not have novel features. Some do.
- Bitcoin market cap: ~\$6.5 billion
- All alts put together: < \$1 billion



Ryan X. Charles  
Founder of Datt ([datt.co](http://datt.co))  
[twitter.com/ryanxcharles](https://twitter.com/ryanxcharles)  
[github.com/ryanxcharles](https://github.com/ryanxcharles)

Code Samples and Slides at:  
[github.com/ryanxcharles/blockchain-university](https://github.com/ryanxcharles/blockchain-university)



# Alternative Uses of Blockchain

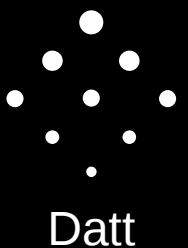
## (besides money)

- Stocks, bonds, fiat currencies, commodities – decentralized ownership, but centralized backing
- Identity, names, rotating keys, revoking keys
- Smart contracts (money or other assets change hands according to complex conditions executed automatically)
- Smart property & Internet of Things (property perform actions, can be owned by cryptographically)
- Proof-of-existence, patents, trademarks, copyright
- DACs and DAOs (distributed autonomous corporations & organizations)
- **If it involves distributed consensus, consider blockchain**



Ryan X. Charles  
Founder of Datt ([datt.co](http://datt.co))  
[twitter.com/ryanxcharles](https://twitter.com/ryanxcharles)  
[github.com/ryanxcharles](https://github.com/ryanxcharles)

Code Samples and Slides at:  
[github.com/ryanxcharles/blockchain-university](https://github.com/ryanxcharles/blockchain-university)



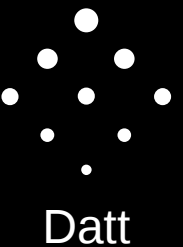
# Permissioned Blockchains

- Bitcoin is **permissionless**. Anyone can use it. Anyone can mine it. No one owns it. (Although some actors have more power than others – more bitcoin, more hash power, commit access, etc.)
- Banks are creating **permissioned** blockchains. Based on the same principles, but not open to the public. They are owned by the banks.
- Exploring **monetary and non-monetary** uses of blockchain technology.
- **R3**: <http://www.coindesk.com/bitcoin-headlines-r3-blockchain-dream-team/>



Ryan X. Charles  
Founder of Datt (datt.co)  
[twitter.com/ryanxcharles](https://twitter.com/ryanxcharles)  
[github.com/ryanxcharles](https://github.com/ryanxcharles)

Code Samples and Slides at:  
[github.com/ryanxcharles/blockchain-university](https://github.com/ryanxcharles/blockchain-university)



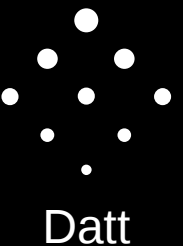
# Blockchains in a Box

- OpenChain – easily produce a blockchain that is optionally attached to bitcoin <https://www.openchain.org/>
- MultiChain – easily produce a blockchain with custom features as a fork of Bitcoin Core <http://www.multichain.com/>
- Can be permissionless (open, anyone can use) or permissioned (closed, only used by select parties)



Ryan X. Charles  
Founder of Datt ([datt.co](http://datt.co))  
[twitter.com/ryanxcharles](https://twitter.com/ryanxcharles)  
[github.com/ryanxcharles](https://github.com/ryanxcharles)

Code Samples and Slides at:  
[github.com/ryanxcharles/blockchain-university](https://github.com/ryanxcharles/blockchain-university)



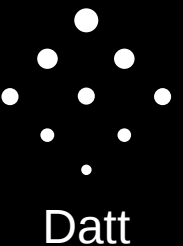
# Blockchains in a Box

- OpenChain – easily produce a blockchain that is optionally attached to bitcoin <https://www.openchain.org/>
- MultiChain – easily produce a blockchain with custom features as a fork of Bitcoin Core <http://www.multichain.com/>
- Can be permissionless (open, anyone can use) or permissioned (closed, only used by select parties)



Ryan X. Charles  
Founder of Datt ([datt.co](http://datt.co))  
[twitter.com/ryanxcharles](https://twitter.com/ryanxcharles)  
[github.com/ryanxcharles](https://github.com/ryanxcharles)

Code Samples and Slides at:  
[github.com/ryanxcharles/blockchain-university](https://github.com/ryanxcharles/blockchain-university)



# Ethereum

- Bitcoin script is not Turing complete (there are some programs that cannot be written with it)
- **Ethereum script is Turing complete** – can program any conceivable contract
- **Bitcoin is designed to solve the problem of digital cash. Ethereum is designed to solve everything else.**
- Bitcoin infrastructure better developed (companies, software, capital), but Ethereum potentially more useful
- See Gav Wood's recent article, "So Ethereum is released."  
<https://medium.com/@gavofyork/so-ethereum-is-released-4291da46b770>



Ryan X. Charles  
Founder of Datt ([datt.co](http://datt.co))  
[twitter.com/ryanxcharles](https://twitter.com/ryanxcharles)  
[github.com/ryanxcharles](https://github.com/ryanxcharles)

Code Samples and Slides at:  
[github.com/ryanxcharles/blockchain-university](https://github.com/ryanxcharles/blockchain-university)





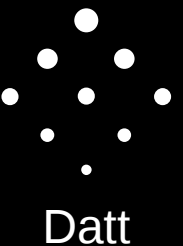
# Non-Blockchains

- **Ripple** – a distributed ledger, based on similar cryptography to bitcoin, but NOT proof-of-work or proof-of-stake
- **Stellar** – a fork of Ripple
- Both of them can track arbitrary assets and rely on third parties to exchange for “real” assets, e.g. withdrawing dollars or bitcoin
- Fall under “cryptofinance” category, but they DO NOT have blockchains!



Ryan X. Charles  
Founder of Datt ([datt.co](http://datt.co))  
[twitter.com/ryanxcharles](https://twitter.com/ryanxcharles)  
[github.com/ryanxcharles](https://github.com/ryanxcharles)

Code Samples and Slides at:  
[github.com/ryanxcharles/blockchain-university](https://github.com/ryanxcharles/blockchain-university)



# A Note on Security

- Bitcoin miners are the world's most powerful supercomputer. (5 billion teraflops vs. 54 thousand teraflops\*)
- Reversing bitcoin transactions requires having an enormous amount of computing power, only achievable by a State actor.
- Reversing a small, private blockchain requires far less computing power and is achievable by small actors. Beware.

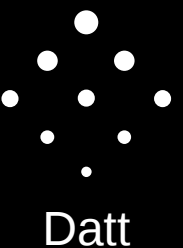
\* Conversion info: <https://www.quora.com/How-to-convert-mflop-s-to-mhash-s> ...  
I calculated assuming 700 million Ghash/s current hash rate, and 700 Mhash/s to 5340 Gflop/s

Current top super computers: <http://www.top500.org/lists/2015/06/>

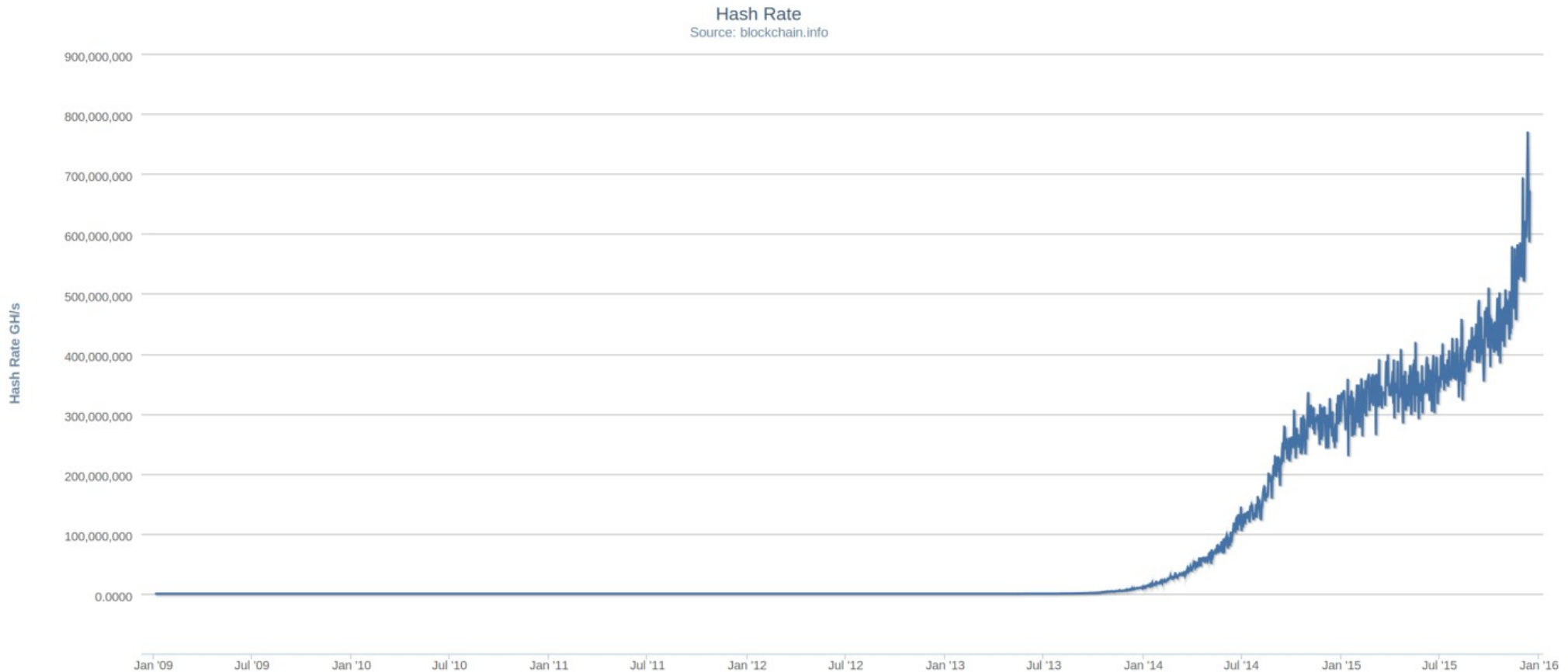


Ryan X. Charles  
Founder of Datt ([datt.co](http://datt.co))  
[twitter.com/ryanxcharles](https://twitter.com/ryanxcharles)  
[github.com/ryanxcharles](https://github.com/ryanxcharles)

Code Samples and Slides at:  
[github.com/ryanxcharles/blockchain-university](https://github.com/ryanxcharles/blockchain-university)

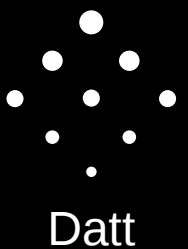


# Bitcoin's All-Time Hash Rate



Ryan X. Charles  
Founder of Datt (datt.co)  
[twitter.com/ryanxcharles](https://twitter.com/ryanxcharles)  
[github.com/ryanxcharles](https://github.com/ryanxcharles)

Code Samples and Slides at:  
[github.com/ryanxcharles/blockchain-university](https://github.com/ryanxcharles/blockchain-university)



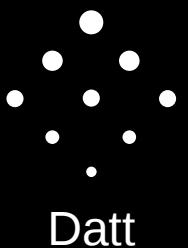
# Colored Coins

- Put meta data on bitcoin transactions to track assets (stock, bonds, whatever) on the bitcoin blockchain.
- Protocols: Open Assets, CoinSpark, Chromaway, Colu, others.
- Upside: Security of bitcoin.
- Downside: Limited block size and thus transaction count. Rules are not enforced by miners.



Ryan X. Charles  
Founder of Datt ([datt.co](http://datt.co))  
[twitter.com/ryanxcharles](https://twitter.com/ryanxcharles)  
[github.com/ryanxcharles](https://github.com/ryanxcharles)

Code Samples and Slides at:  
[github.com/ryanxcharles/blockchain-university](https://github.com/ryanxcharles/blockchain-university)



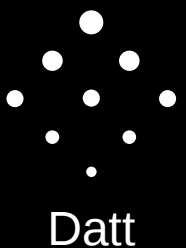
# Two-Way Pegged Sidechains

- Invented by Blockstream, theoretically allows transfer of bitcoin to other blockchains by “pegging” - proof-of-peg lets you spend bitcoin on the sidechain, proof-of-unpeg lets you retrieve bitcoin back on normal chain
- Upside: Security of bitcoin, network effect of bitcoin, unlimited advanced uses of blockchain.
- Downside: Not yet implemented.



Ryan X. Charles  
Founder of Datt ([datt.co](http://datt.co))  
[twitter.com/ryanxcharles](https://twitter.com/ryanxcharles)  
[github.com/ryanxcharles](https://github.com/ryanxcharles)

Code Samples and Slides at:  
[github.com/ryanxcharles/blockchain-university](https://github.com/ryanxcharles/blockchain-university)



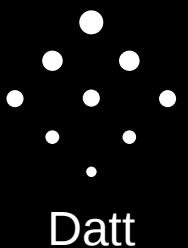
# Technology Summary

- Bitcoin
- Altcoins
- Ethereum
- Non-Blockchain (Ripple, Stellar)
- Permissioned Blockchains (banks)
- Bitcoin-dependent: Colored Coins; Sidechains
- ...hard to beat bitcoin's security and network effect



Ryan X. Charles  
Founder of Datt ([datt.co](http://datt.co))  
[twitter.com/ryanxcharles](https://twitter.com/ryanxcharles)  
[github.com/ryanxcharles](https://github.com/ryanxcharles)

Code Samples and Slides at:  
[github.com/ryanxcharles/blockchain-university](https://github.com/ryanxcharles/blockchain-university)





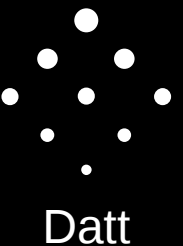
# Bitcoin Economy

- Wallets
- Exchanges
- APIs and Developer Tools
- Payment Gateways
- Miners
- Storage
- Merchants
- Investment
- Non-Monetary Advanced Uses
- Financial Services



Ryan X. Charles  
Founder of Datt ([datt.co](http://datt.co))  
[twitter.com/ryanxcharles](https://twitter.com/ryanxcharles)  
[github.com/ryanxcharles](https://github.com/ryanxcharles)

Code Samples and Slides at:  
[github.com/ryanxcharles/blockchain-university](https://github.com/ryanxcharles/blockchain-university)



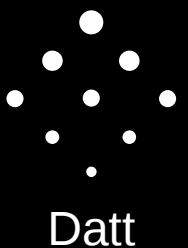
# Miners



Graphics by BitPay, Bitcoin Magazine & Josh Dykgraaf

Ryan X. Charles  
Founder of Datt ([datt.co](http://datt.co))  
[twitter.com/ryanxcharles](https://twitter.com/ryanxcharles)  
[github.com/ryanxcharles](https://github.com/ryanxcharles)

Code Samples and Slides at:  
[github.com/ryanxcharles/blockchain-university](https://github.com/ryanxcharles/blockchain-university)



Datt

# Wallets

## WALLETS

"At Coinbase, we're excited about the progress made thus far but we're still in the early days of the technology and even more excited about the app ecosystem and what the future of Bitcoin applications will look like."

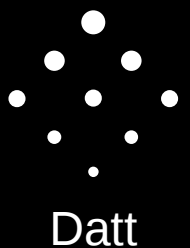
**Adam White**  
VP of Business Development,  
Coinbase



Graphics by BitPay, Bitcoin Magazine & Josh Dykgraaf

**Ryan X. Charles**  
Founder of Datt ([datt.co](http://datt.co))  
[twitter.com/ryanxcharles](https://twitter.com/ryanxcharles)  
[github.com/ryanxcharles](https://github.com/ryanxcharles)

Code Samples and Slides at:  
[github.com/ryanxcharles/blockchain-university](https://github.com/ryanxcharles/blockchain-university)



Datt



# Storage

## STORAGE

"Bitcoin paved the way to decentralized security, and will jumpstart the usage of personal privacy devices."

Eric Larchevêque  
CEO, Ledger

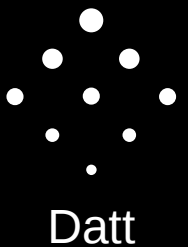
"Today there are more than 100,000 Bitcoin transactions per day for more than \$100 million and there are more than 5,000 servers acting as nodes of the network. Bitcoin is a lot less likely to disappear today than it was 2 years ago when the price was over \$1,000 per Bitcoin."



Graphics by BitPay, Bitcoin Magazine & Josh Dykgraaf

Ryan X. Charles  
Founder of Datt (datt.co)  
[twitter.com/ryanxcharles](https://twitter.com/ryanxcharles)  
[github.com/ryanxcharles](https://github.com/ryanxcharles)

Code Samples and Slides at:  
[github.com/ryanxcharles/blockchain-university](https://github.com/ryanxcharles/blockchain-university)



Datt

# Exchanges

## EXCHANGES

"Bitcoin startups like Gemini are ushering in a new chapter of legitimacy and integrity that will allow Bitcoin to go mainstream and fulfill its ultimate promise."

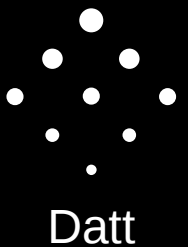
**Tyler Winklevoss**  
Co-Founder and CEO, Gemini



Graphics by BitPay, Bitcoin Magazine & Josh Dykgraaf

**Ryan X. Charles**  
Founder of Datt ([datt.co](http://datt.co))  
[twitter.com/ryanxcharles](https://twitter.com/ryanxcharles)  
[github.com/ryanxcharles](https://github.com/ryanxcharles)

Code Samples and Slides at:  
[github.com/ryanxcharles/blockchain-university](https://github.com/ryanxcharles/blockchain-university)



Datt



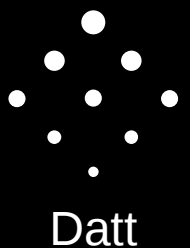
# Payment Processors



Graphics by BitPay, Bitcoin Magazine & Josh Dykgraaf

Ryan X. Charles  
Founder of Datt ([datt.co](http://datt.co))  
[twitter.com/ryanxcharles](https://twitter.com/ryanxcharles)  
[github.com/ryanxcharles](https://github.com/ryanxcharles)

Code Samples and Slides at:  
[github.com/ryanxcharles/blockchain-university](https://github.com/ryanxcharles/blockchain-university)





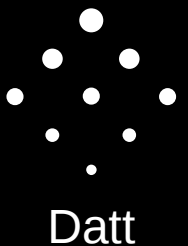
# Merchants



Graphics by BitPay, Bitcoin Magazine & Josh Dykgraaf

Ryan X. Charles  
Founder of Datt ([datt.co](http://datt.co))  
[twitter.com/ryanxcharles](https://twitter.com/ryanxcharles)  
[github.com/ryanxcharles](https://github.com/ryanxcharles)

Code Samples and Slides at:  
[github.com/ryanxcharles/blockchain-university](https://github.com/ryanxcharles/blockchain-university)



# Investment

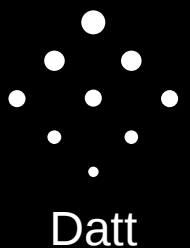


Graphics by BitPay, Bitcoin Magazine & Josh Dykgraaf



Ryan X. Charles  
Founder of Datt ([datt.co](http://datt.co))  
[twitter.com/ryanxcharles](https://twitter.com/ryanxcharles)  
[github.com/ryanxcharles](https://github.com/ryanxcharles)

Code Samples and Slides at:  
[github.com/ryanxcharles/blockchain-university](https://github.com/ryanxcharles/blockchain-university)





# Media & Advocacy

## MEDIA & ADVOCACY

"We are privileged to be at the nexus where information meets technology, using a multimedia platform to support the adoption and innovation of Bitcoin and the blockchain. In only two years, the audience for digital currency news has exploded from Fintech specialists to the man on the street. This is now a mainstream media topic, and what happens in Bitcoin happens to the world."

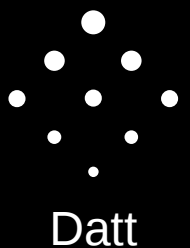
**David Bailey**  
CEO, BTC Media



Graphics by BitPay, Bitcoin Magazine & Josh Dykgraaf

**Ryan X. Charles**  
Founder of Datt ([datt.co](http://datt.co))  
[twitter.com/ryanxcharles](https://twitter.com/ryanxcharles)  
[github.com/ryanxcharles](https://github.com/ryanxcharles)

Code Samples and Slides at:  
[github.com/ryanxcharles/blockchain-university](https://github.com/ryanxcharles/blockchain-university)



# Advanced Uses of Blockchain

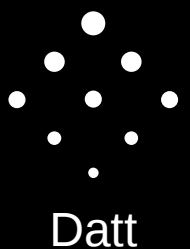


Graphics by BitPay, Bitcoin Magazine & Josh Dykgraaf



**Ryan X. Charles**  
Founder of Datt ([datt.co](http://datt.co))  
[twitter.com/ryanxcharles](https://twitter.com/ryanxcharles)  
[github.com/ryanxcharles](https://github.com/ryanxcharles)

Code Samples and Slides at:  
[github.com/ryanxcharles/blockchain-university](https://github.com/ryanxcharles/blockchain-university)





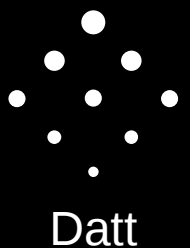
# Financial Services



Graphics by BitPay, Bitcoin Magazine & Josh Dykgraaf

Ryan X. Charles  
Founder of Datt ([datt.co](http://datt.co))  
[twitter.com/ryanxcharles](https://twitter.com/ryanxcharles)  
[github.com/ryanxcharles](https://github.com/ryanxcharles)

Code Samples and Slides at:  
[github.com/ryanxcharles/blockchain-university](https://github.com/ryanxcharles/blockchain-university)



# Implementations of Bitcoin

- Bitcoin Core – Original C++ implementation, maintained by “Core” developers
- BitcoinJ – The first re-implementation
- Btcd – A full implementation in Go
- bitcore, bitcoinjs, fullnode – Javascript & Node.js
- rust-bitcoin – Rust
- python-bitcoinlib, caesure – Python



Ryan X. Charles  
Founder of Datt ([datt.co](http://datt.co))  
[twitter.com/ryanxcharles](https://twitter.com/ryanxcharles)  
[github.com/ryanxcharles](https://github.com/ryanxcharles)

Code Samples and Slides at:  
[github.com/ryanxcharles/blockchain-university](https://github.com/ryanxcharles/blockchain-university)

