Blockchains & Distributed Ledgers

Lecture 09

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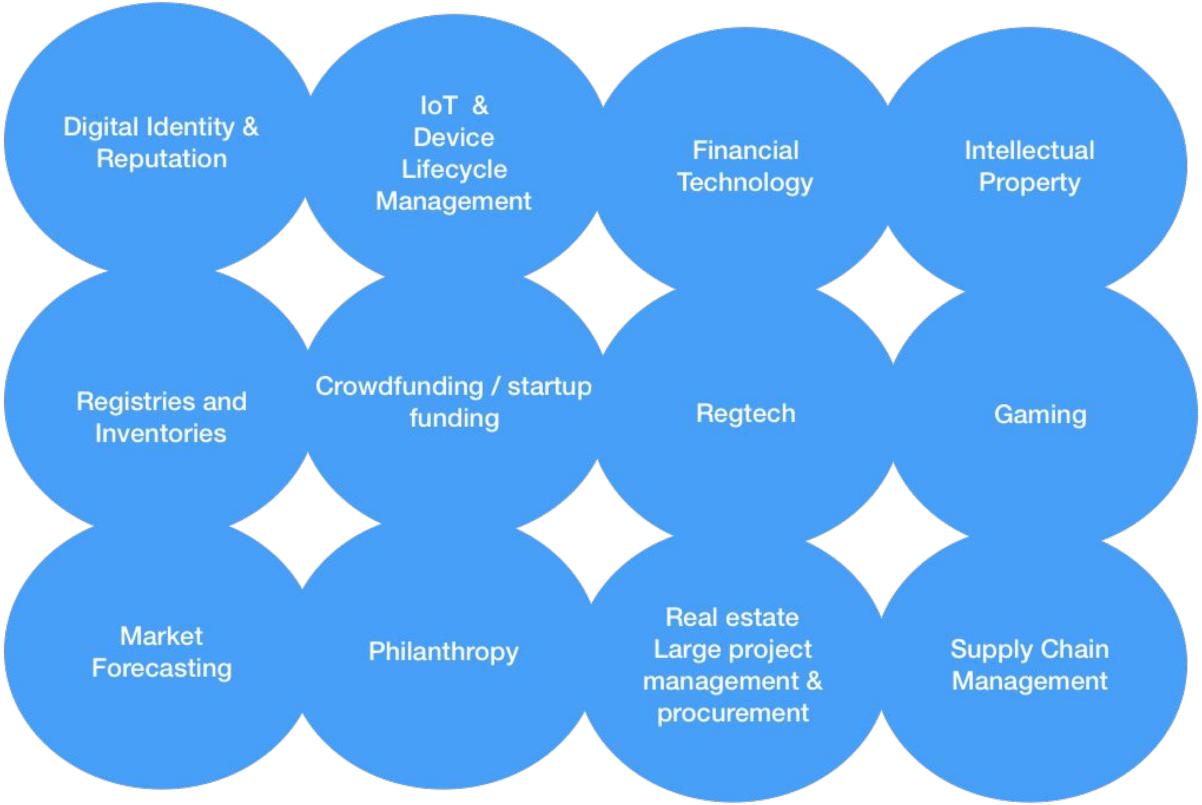
Slide credits: DK, Aggelos Kiayias

(Possible) Applications of DLT



Digital Identity & Reputation

IoT & Device Lifecycle Management

Financial Technology

Intellectual Property

Registries and Inventories

Crowdfunding / startup funding

Regtech

Gaming

Market Forecasting

Philanthropy

Real estate Large project management & procurement

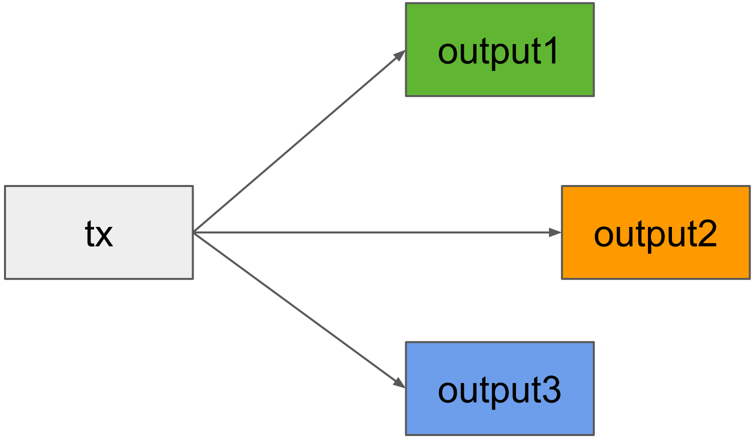
Supply Chain Management

Use an independent DL or piggyback on existing?

Scheme	**Advantage**	**Disadvantage**
Piggybacking	Potential for higher assurance	Need to engineer or program protocol rules into existing ledger
Independent	Ability to customise protocol & enforce individual properties	Might attract a small set of initial nodes and initially be less trustworthy

Piggybacking Example - Coloured Coins

- Even though Bitcoin can be treated as fungible, it is not:
  - the smallest Bitcoin denomination (satoshi) can be tracked following some convention
- “Colouring" outputs so they represent specific assets



Piggybacking Example - Coloured Coins

- Use of the OP_RETURN opcode
  - OP_RETURN signifies that a transaction output is invalid (and unspendable)
  - Can be followed by 80 bytes of data
  - Paying to an OP_RETURN enables storing personal data on the blockchain
- Burn one output to define colouring information for the (rest of the) transaction
- Bitcoin transaction fees still apply
  - transactions have to be formed with OP_RETURN
  - a small amount of storage permitted
- The secret-key of the coloured account controls asset ownership
  - Marker outputs (via OP_RETURN) can be used to further specify quantities transferred etc
  - Accounts should hold a balance to ensure the ability to transfer them onwards

Piggybacking Example - Coloured Coins

- Bitcoin miners do not enforce proper rules of colouring
- Coloured transactions are treated as regular transactions by “colour-blind” miners
- Colouring rules might not be respected by an indifferent or malicious miner
    - Parsing algorithms for colours should take this into account

Applications

Digital economy (on a blockchain)

- Use a blockchain to record monetary transactions
- Create new money based on pre-determined algorithm

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Issues

- Why would people use on-chain tokens as *money* instead of as commodities? Why would someone sell BTC, if they expect its (USD) price to increase?
- How to accurately valuate a blockchain-based economy? (e.g., market capitalization)

Name registry (on a blockchain)

- Use a blockchain to register names
- Useful in the context of DNS (domain name system) and public-key directories
- Censorship-resistant
- Examples:
  - *Namecoin*: separate blockchain, based on Bitcoin protocol
  - *Blockstack*: piggybacking on the Bitcoin blockchain, as in the case of colored coins
  - *ENS (Ethereum Name Service)*: domain registry implemented as an Ethereum smart contract

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Issues

- How to connect blockchain-issued names with the rest of the internet?
- What if some domains *should be* taken down?

Land ownership (on a blockchain)

- Issue a new digital asset linked to land title
- Store information in the digital asset that links to an information resource
  - E.g., insert a URL to real-world registry or an identifier for a torrent file
- Digital asset becomes representation of ownership
  - He who controls the asset can prove or transfer ownership of the linked land
- Same idea can be extended to any real-world asset

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Issues

- What happens if the information source is no longer available (e.g., the URL breaks)?
- What if the legal system does not recognize on-chain representation?

Gaming and art collection (on a blockchain)

- In-game currency on a blockchain
  - E.g., Ethereum-based game tokens
- Digital collectibles
  - E.g., trading cards, virtual animans (CryptoKitties), NFTs (Non-Fungible Tokens) of art works
- On-chain games
  - Gambling, strategy games, social network games, ...

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  - Gambling, strategy games, social network games, ...

Issues

- Gaming companies typically want control of in-game economy - why would decentralization benefit them?
- If some aspects are off-chain (e.g., game graphics or real-world art work), what happens if the company does not support the token system anymore?
- Why would users pay fees to play, when centralized options are free (or, at worst, pay-to-win)?

Supply chain tracking (on a blockchain)

- Real-world products
  - E.g., clothes, shoes, meat, olive oil, even diamonds
- Create a digital fingerprint of the object
- Register the fingerprint on a blockchain
- Record every change in the object’s state
  - E.g., creation at source, transportation, selling/buying

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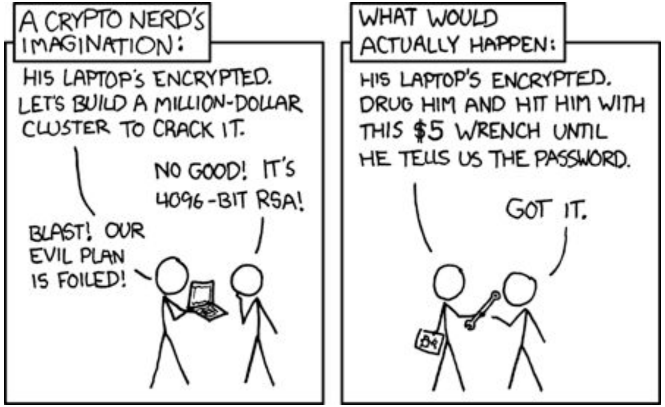
A CRYPTO NERD'S IMAGINATION:
HIS LAPTOP'S ENCRYPTED. LET'S BUILD A MILLION-DOLLAR CLUSTER TO CRACK IT.
NO GOOD! IT'S 4096-BIT RSA!
BLAST! OUR EVIL PLAN IS FOILED!
WHAT WOULD ACTUALLY HAPPEN:
HIS LAPTOP'S ENCRYPTED. DRUG HIM AND HIT HIM WITH THIS $5 WRENCH UNTIL HE TELLS US THE PASSWORD.
GOT IT.

Issues

- How to create a fingerprint (unique digital representation(of a physical object?
- How to make sure that people that handle the object actually record its state changes? What if someone bribes someone to insert false data on the chain?

Philanthropy (on a blockchain)

- An NGO/philanthropic organization creates a smart contract
  - E.g., to collect funds for building a school
- People send funds to the contract
- The contract keeps the funds in escrow:
  - When a proof that the project is complete is provided, the contract releases the funds
  - If a deadline passes, the remaining funds are returned to the participants

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Issues

- What kind of (secure) proofs of real-world actions could be understandable by a smart contract?
- How can you prevent embezzlement, i.e., a corrupted official publishing incorrect proofs?

Prediction Markets

- A market that enables trading on future events
- Oracles provide real-world information on whether an event occurred
- Example: “10 tornadoes will hit USA in 2020”
  - participants bet in favour or against the event
  - market shares: YES = α, NO = $1-\alpha$; total investment: X; probability of event happening: p
  - expected Profit of YES = $pX - \alpha X$
- Use prediction markes for:
  - Gambling, insurance purposes, ...

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Issues

- Trust in the oracle? Can a decentralized oracle for real-world information exist?
- Events may not be well-defined (e.g., is Puerto Rico part of the USA?)

IoT and micropayments (on a blockchain)

- IoT devices connected to the internet
    - E.g., smart fridges, sensors
- Utility meters
    - E.g., electricity or water consumption
- User pays in real-time with multiple “micro”-payments to the service provider
- Alternative to subscription model
- Monetization of user data: User gets income for selling their personal data

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- Monetization of user data: User gets income for selling their personal data

Issues

- Blockchains don’t scale - fees increase dramatically as usage tends to congestion
- Blockchains are not private - why would you share your daily data with the whole world?
- Even if you got paid for it, would you want to sell your personal life?

Crowdfunding (on a blockchain)

- A project creates a smart contract that issues tokens
  - Initial Coin Offering (ICO), ERC20 Ethereum tokens
- Users give coins in exchange for tokens
  - Buy tokens with ETH
- Tokens can:
  - Be used in a future platform that the project creates (utility tokens)
  - Be used as investment, resold, offer yield (securities)

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Issues

- How to guarantee that project will not run away with the funds (i.e., exit scam)?
- What if project tries to scam investors and authorities, e.g., claim a security is utility token?
- Are the promises of the project verified/regulated? Will the project face penalties for lying?

Market Capitalization

Market capitalization (of cryptocurrencies)

- Centralized exchanges are sources of price
    - Price of X: the latest price for which a single X token was sold (in exchange for USD/GBP/Bitcoin/altcoins/…)
- Market cap: <number of coins in circulation> · <price>

💰 💰 💰

Product name	Circulating Tokens	Price (USD)	Market Cap (USD)	Total MC (USD)

1 BTC

💰💰💰

Product name	Circulating Tokens	Price (USD)	Market Cap (USD)	Total MC (USD)
Bitcoin	**1**			

Sell 1 BTC for 1 USD

1 BTC

💰💰💰

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Bitcoin	1			

1 USD

1 BTC

Product name	Circulating Tokens	Price (USD)	Market Cap (USD)	Total MC (USD)
Bitcoin	1	**1 USD**	**1 USD**	**1 USD**

1 USD

1 BTC

1 ETH

Product name	Circulating Tokens	Price (USD)	Market Cap (USD)	Total MC (USD)
Bitcoin	1	1 USD	1 USD	1 USD
Ethereum	**1**			

Sell 1 ETH for 1 USD

1 USD

1 BTC

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Bitcoin	1	1 USD	1 USD	1 USD
Ethereum	1			

1 ETH

1 BTC

1 USD

Product name	Circulating Tokens	Price (USD)	Market Cap (USD)	Total MC (USD)
Bitcoin	1	1 USD	1 USD	**2 USD**
Ethereum	1	**1 USD**	**1 USD**	

Sell 0.5 ETH for 1 BTC

1 ETH

1 BTC

1 USD

Product name	Circulating Tokens	Price (USD)	Market Cap (USD)	Total MC (USD)
Bitcoin	1	1 USD	1 USD	2 USD
Ethereum	1	1 USD	1 USD	

0.5 ETH,
1 BTC

0.5 ETH

1 USD

Product name	Circulating Tokens	Price (USD)	Market Cap (USD)	Total MC (USD)
Bitcoin	1	1 USD	1 USD	**3 USD**
Ethereum	1	**2 BTC**	**2 USD**	

0.5 ETH,
1 BTC

Sell 0.5 BTC for 1 USD

0.5 ETH

1 USD

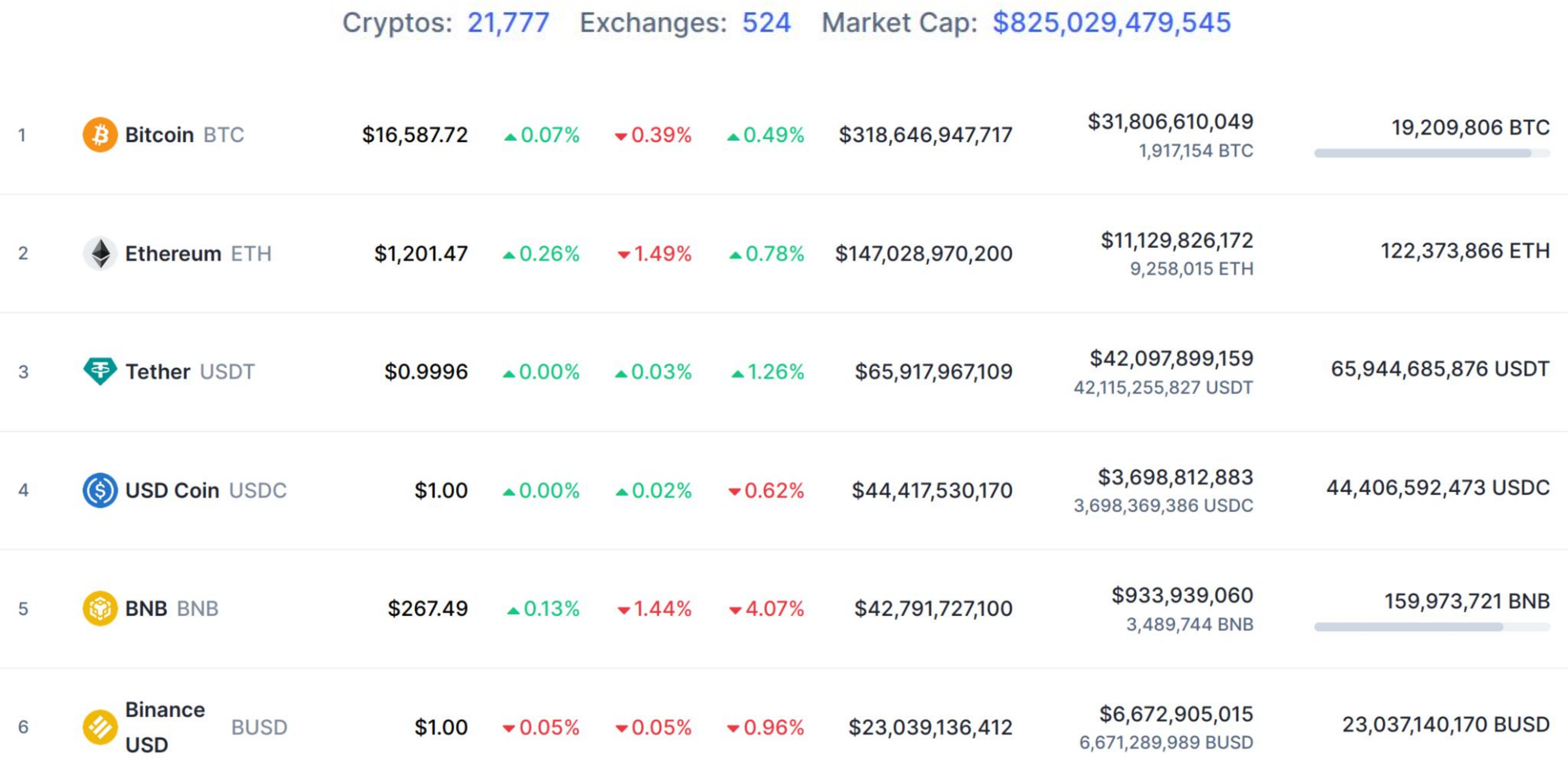
Product name	Circulating Tokens	Price (USD)	Market Cap (USD)	Total MC (USD)
Bitcoin	1	1 USD	1 USD	3 USD
Ethereum	1	2 BTC	2 USD	

0.5 ETH,
0.5 BTC,
1 USD

0.5 ETH

0.5 BTC

Product name	Circulating Tokens	Price (USD)	Market Cap (USD)	Total MC (USD)
Bitcoin	1	**2 USD**	**2 USD**	**6 USD**
Ethereum	1	2 BTC	**4 USD**	



Cryptos: 21,777 Exchanges: 524 Market Cap: $825,029,479,545

1	Bitcoin BTC	$16,587.72	▲0.07%	▼0.39%	▲0.49%	$318,646,947,717	$31,806,610,049 1,917,154 BTC	19,209,806 BTC
2	Ethereum ETH	$1,201.47	▲0.26%	▼1.49%	▲0.78%	$147,028,970,200	$11,129,826,172 9,258,015 ETH	122,373,866 ETH
3	Tether USDT	$0.9996	▲0.00%	▲0.03%	▲1.26%	$65,917,967,109	$42,097,899,159 42,115,255,827 USDT	65,944,685,876 USDT
4	USD Coin USDC	$1.00	▲0.00%	▲0.02%	▼0.62%	$44,417,530,170	$3,698,812,883 3,698,369,386 USDC	44,406,592,473 USDC
5	BNB BNB	$267.49	▲0.13%	▼1.44%	▼4.07%	$42,791,727,100	$933,939,060 3,489,744 BNB	159,973,721 BNB
6	Binance USD BUSD	$1.00	▼0.05%	▼0.05%	▼0.96%	$23,039,136,412	$6,672,905,015 6,671,289,989 BUSD	23,037,140,170 BUSD

https://coinmarketcap.com

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Issues

- Market cap may be artificially increased
  - E.g., tokens or dubious “coins” sold for other cryptocurrency
- Question: What is the ratio of *real-world* money to *market cap*? In other words, how much *real-world* money is *actually* in the market?

Decentralized Finance

Finance

- {creation, management, investment} of **money** and **financial assets**
- Financial assets: non-physical assets whose value is derived by contractual claim
  - Bank deposits, stocks, bonds, loans
- Financial services
  - Lending/borrowing, issuing securities, managing funds
- Financial markets: marketplace for **trading** financial assets

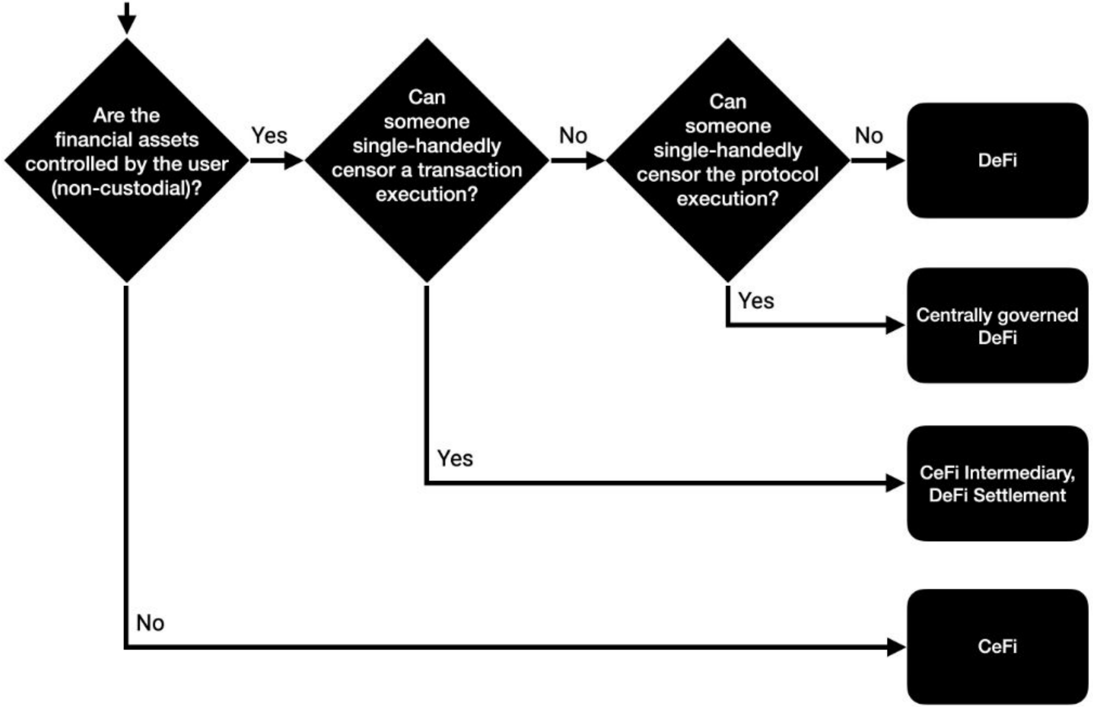
Decentralized Finance (DeFi)

- Financial products and services on decentralized infrastructure
  - Typically Ethereum-based
- Do not rely on centralized intermediaries
  - E.g., exchanges, banks, brokers
- Utilize the security of an underlying blockchain system
- Open to hazards and attacks that stem from public/decentralized nature of blockchains

Securities

- Security: a fungible, negotiable, financial instrument that has some value
  - stock (representing ownership of company) - **equity security**
  - bond (representing a creditor relationship with company/government) - **debt security**
- In the US (cf. Securities and Exchange Commission (SEC) v. W.J. Howey Co) a security is:
  - a contract, transaction, or scheme whereby a person **invests** his money in a **common enterprise**...
    - *Horizontal commonality*: Investors' assets are joined and they share the risk and benefits
    - *Vertical commonality*: Investors' fortunes are linked and dependent upon the efforts of those seeking the investment (**narrow** (investors' profits rise and fall together with promoter's) vs. **broad** (investors' profits depend on promoter's expertise and performance))
  - … and is led to **expect** profits solely from the efforts of the promoter or a third party

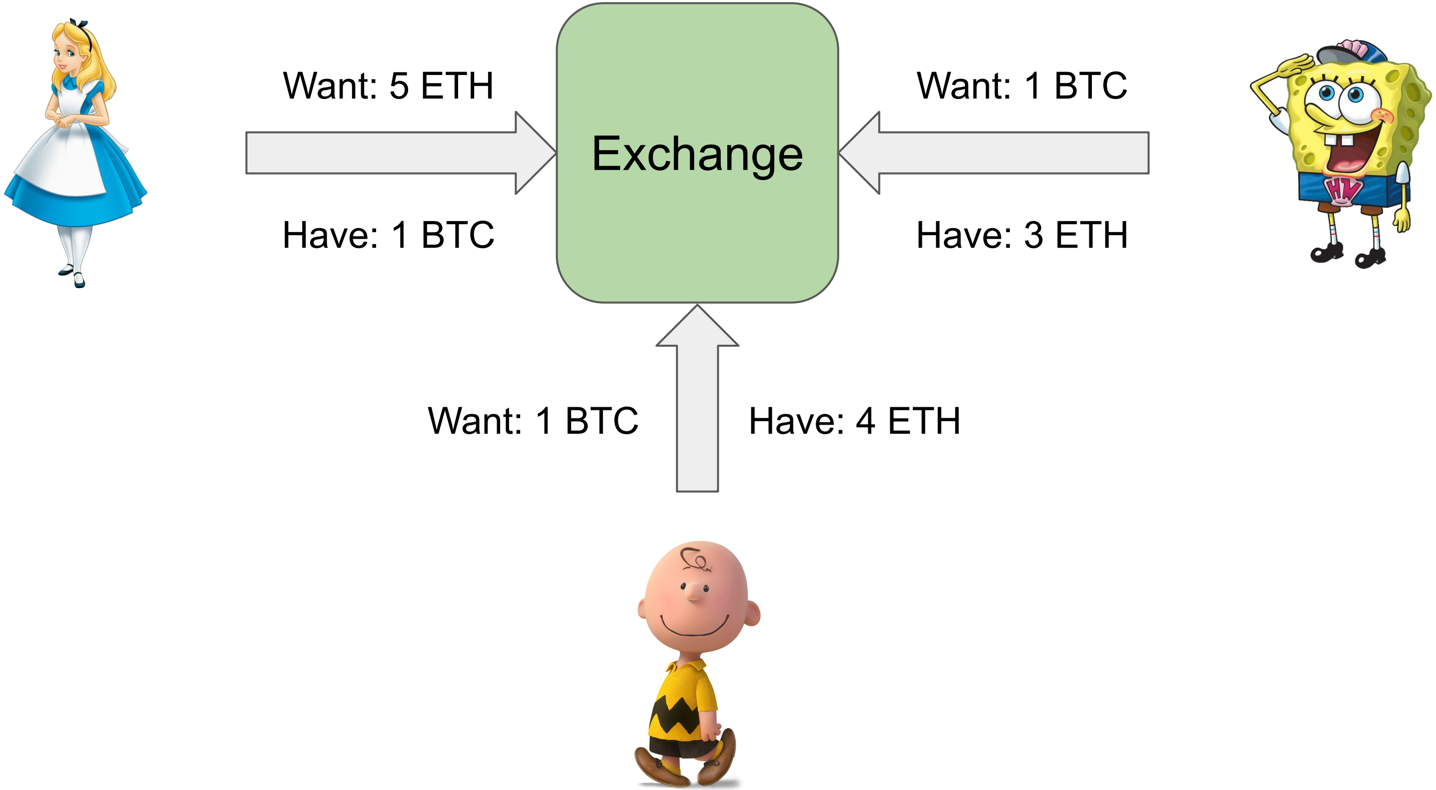
Decentralized Finance (DeFi)



Are the financial assets controlled by the user (non-custodial)?
Yes
Can someone single-handedly censor a transaction execution?
No
Can someone single-handedly censor the protocol execution?
No
DeFi
Yes
Centrally governed DeFi
Yes
CeFi Intermediary, DeFi Settlement
No
CeFi

Source: https://berkeley-defi.github.io/f21

Exchanges/Marketplaces



Want: 5 ETH

Have: 1 BTC

Exchange

Want: 1 BTC

Have: 3 ETH

Want: 1 BTC

Have: 4 ETH

Decentralized Exchanges (DEXs)

- Completely on-chain
  - Trades between native chain currency (e.g., ETH) and on-chain tokens (e.g., ERC20)
- Censorship resistance
  - Availability depends on underlying blockchain’s safety & liveness
- Differences from centralized (server-based) exchanges
  - (Blockchain) fees for creating orders
  - (Blockchain) fees for cancelled orders
  - Slower matching
  - No KYC and AML provisions

Decentralized Exchanges (DEXs), Attacks

- Front-running
  - Adversary can use gas price to front-run a trading tx
  - Miners choose tx ordering → can front-run plain users
  - Also exists in centralized exchanges (esp. if unregulated)
    - Exchange owner can see all txs, control execution order, and increase/decrease price arbitrarily to “burn” customers (both short and long)
- Some mining pools offer front-running *as a feature* (e.g., Ethermine)

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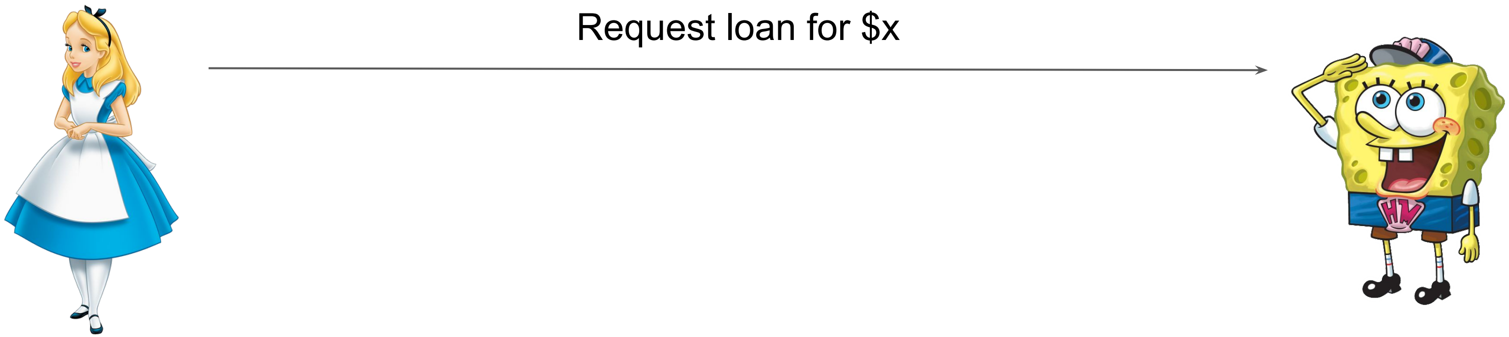
- Insertion (aka sandwitching) attack
  - U creates a “buy” order TX_U, e.g., buy BTC for ETH
  - Attacker inserts before TX_U (front-running) a “sell” order and gets x BTC for y_1 ETH, *moving the price* of BTC-ETH
  - U’s order is executed for the decreased price
  - Attacker inserts a “buy” order after TX_U, which gets back y_2 ETH for x BTC
  - Attack profit: $y_2 - y_1$

(Real-world) Loans



Request loan for $x

Borrower

Lender
(Bank)

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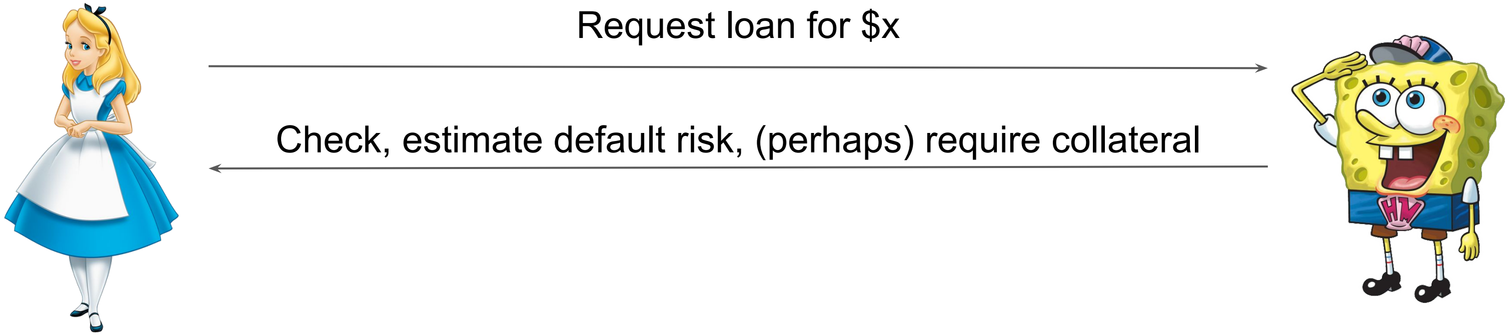

Request loan for $x

Check, estimate default risk, (perhaps) require collateral

Borrower

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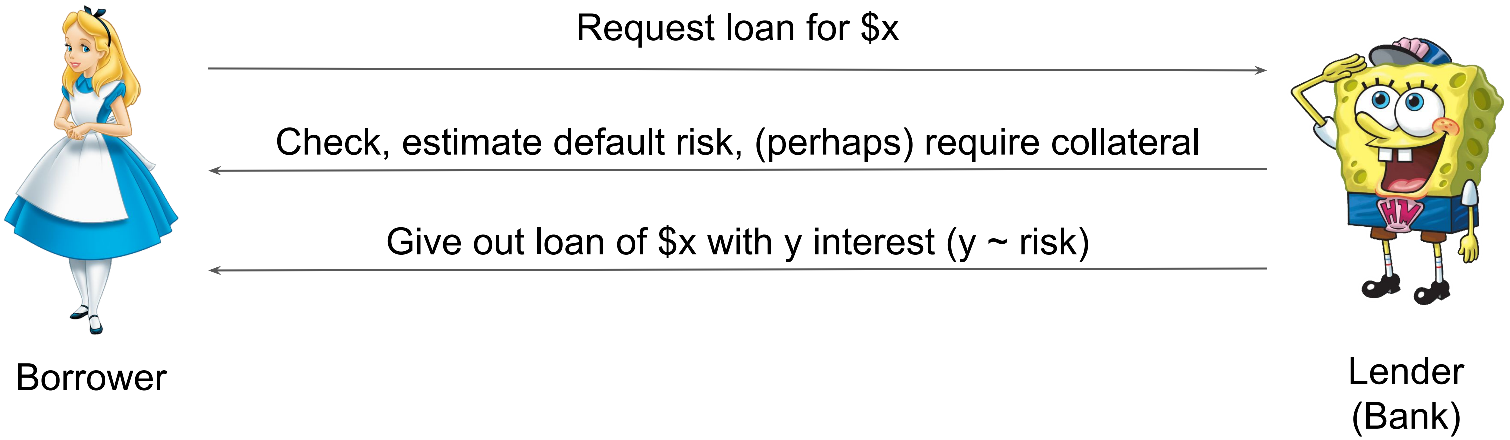

Request loan for $x

Check, estimate default risk, (perhaps) require collateral

Give out loan of $x with y interest (y ~ risk)

Borrower

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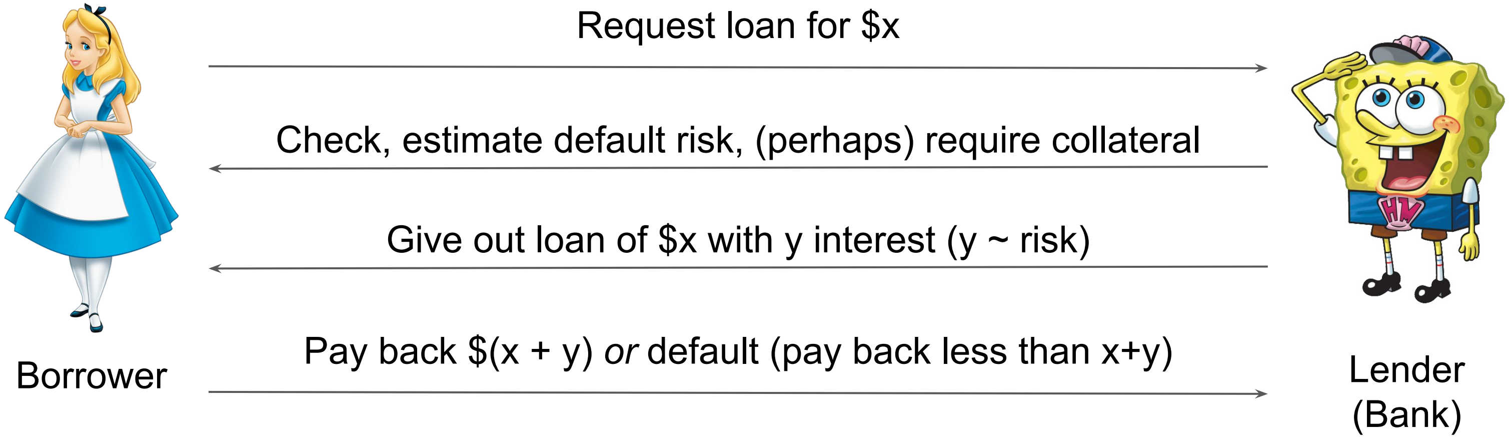
(Real-world) Loans



Request loan for $x

Check, estimate default risk, (perhaps) require collateral

Give out loan of $x with y interest (y ~ risk)

Pay back $(x + y) *or* default (pay back less than x+y)

Borrower

Lender
(Bank)

Decentralized Loans

- Assumption: **Oracle** that reports (real-world) asset prices
    - E.g., USD prices
    - Typically semi or completely centralized
- Lender deposits principal **capital** to a “vault”
    - The vault is simply the service’s smart contract
- Borrower deposits **collateral** to borrow from vault
    - Typically over-collateralized: value(*collateral*) (in real prices) > value(*loan*)
    - If collateral value drops significantly, loan can be automatically liquidated
        - Liquidator repays debt and gets the collateral at a discount
- Borrower returns loan + interest to vault
    - Lender can withdraw principal capital and received interest

Flash Loans

- A loan that occurs in a **single atomic** transaction
- Lender adds principal capital (“liquidity”) to a smart contract pool
- Within a single transaction:
    - Smart contract pool transfers x assets from the pool to borrower’s account
    - Borrower uses x assets as they want
    - Borrower transfers x assets plus some fee to the pool
    - If any step of the above fails (e.g., borrower cannot repay the pool), tx fails
- No default risk!

Decentralized/Flash Loans, Attacks

- Price oracle manipulation
  - Control collateral requirements

Decentralized/Flash Loans, Attacks

- Price oracle manipulation
  - Control collateral requirements
- Risk-free arbitrage
  - DEXs may offer different prices on the same trading pair
  - Use flash loan to:
    - i) buy on one DEX
    - ii) sell on the other (at higher price)
    - iii) repay loan+fees and profit depending on price difference

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- Washtrading
  - Sell and buy the same asset to create misleading activity, e.g., to artificially increase trading volume and show “demand”
  - Centralized cryptocurrency exchanges often perform washtrading (e.g., [1, 2, 3])
  - Illegal in USA *regulated* markets since 1936

Stablecoins

Fiat-backed stablecoins

- Centralized issuer of “stable price” tokens
- How it works
  - User deposits $1 to service’s bank account
  - Service issues 1 token in exchange
  - *As long as* token remains in circulation, the service keeps $1 in escrow
  - *Whenever* user wants, they can redeem 1 token for $1
- Why use such stablecoins instead of USD directly?
  - Exchanges
    - avoid regulation
    - settle inter-exchange transfers faster
  - Users
    - bypass capital controls
    - avoid KYC/AML requirements
    - launder illegal profit

Fiat-backed stablecoins

- If 1-1 promise (silently) breaks
  - Service issues loans (fractional reserve), assuming default risk
  - Service can insert (artificial) liquidity into the market (to pump price/market cap of assets)
- If regulation tightens
  - The broken 1-1 promise becomes public knowledge
  - Trust in the system decreases, “stable” price no longer stable (reflecting default risk)
  - Liquidity evaporates
- Tether (*by far* the largest “stablecoin”)
  - Opaque (*no audits,* unknown reserves, unknown affiliations, can refuse redemptions at will)
  - Repeatedly misleading behaviour (NYAG, CFTC)
  - *It is known* that Tether does not have $1 for every USDT
  - Circulation: $4B until 2019, $21B end of 2020, $74B in Nov 2021, $65.9B in Nov 2022
  - “Daily trading volume” across all exchanges: $87B (>2x Bitcoin’s)
  - Almost every major exchange trades Tether (and is open to Tether collapse risk)

Crypto-backed stablecoins

- (1+x)-1 backing by crypto reserves
- (Centralized) price oracles
- How it works
    - Assume: 1 ETH = $1, x = 1
    - Deposit 2 ETH and get 1 stablecoin (over-collateralized)
    - If price(ETH) > $0.5: stablecoin's price unchanged
    - If price(ETH) < $0.5: stablecoin liquidated, investor receives 2 ETH
- Example: Dai

Crypto-backed stablecoins

- Leveraged investment
  a. Buy 1 coin with 2 ETH
  b. Buy 1 ETH with 1 coin
  c. Increased demand for ETH → ETH price ↑
  d. ETH price ↑ (eg. 1 ETH = $2)→sell 0.5 ETH for 1 coin, redeem coin for 2 ETH (profit: 0.5 ETH)
  e. Go to (a) (perpetual motion machine)
- What if ETH price drops?
  a. Stablecoins liquidated for ETH
  b. Investors sell ETH to cut losses → Uncertainty from liquidations, ETH supply ↑ → price ↓
  c. Go to (a) (death spiral)
- Example: March 2020, MakerDAO had to *centrally intervene and inject liquidity* to avoid complete shutdown
  - What happens if market collapses and external pockets not deep enough?

Algorithmic stablecoins

- (Centralized) price oracle
- Principal idea: *Quantity Theory of Money**
  - MV = PT ([Money supply] * [Velocity] = [weighted Price average] * [sum of all Transactions])
  - If V, T remain the same, P (prices, i.e., inflation) follow M (money supply)
  - By definition true in a snapshot, *cannot* be relied on for predictions
- Two types of assets
  - “stable” coins
  - bonds
- How it works
  - coin price > $1: automatically issue and distribute new coins (coin supply ↑ → price ↓)
  - coin price < $1: sell bonds for coins (coin supply ↓ → price ↑)
- Bonds:
  - Buy bond in auction (face value: $1, auction price: y)
  - ~~When~~ If coin price gets above $1 again, redeem bond to receive new coins (profit = 1 - y)

* Irving Fisher. “The Purchasing Power of Money” (1911)

Algorithmic stablecoins

- No such project has survived for long
  - Nubits (*“World's Best Stable Digital Currencies”*): $0.12
  - Basis (*“an Algorithmic Stablecoin Pegged to 1 USD”*): $0.04
  - Terra (*“stable rewards in all economic conditions”*): $0.02
- Why fail?
  - price ↑ → bond-holders and investors receive newly issued coins
  - price ↓ → investors can only buy bonds and *have faith* that price will go up again
  - if price does not go up quickly
    - lost profit (opportunity cost) ↑
    - if lost profit > bond profit, no reason to remain invested

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