

Decentralized Finance

Introduction and Overview of DeFi

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What Is Finance?

- Finance is the process that involves the creation, management, and investment of money and financial assets
- Financial assets/financial instruments:
 - a non-physical asset whose value is derived from a contractual claim
 - Bank deposits, stocks, bonds, loans, derivatives
- Financial services
 - banking, lending/borrowing, securities, insurance, trusts, funds
- Financial markets: marketplace for trading financial assets



Traditional Finance (CeFi)

(Centralized) financial institutions provide financial services

- Banks, securities/insurance/trust investment/fund management companies, etc. (title 31 of the United States Code)
- Hold custodies of customers' funds/assets
 - Can freeze accounts
- Serves as intermediaries for transactions
 - Can censor transactions
 - Take fees (rent seeking)
- Adhere to strict on-boarding & continuous compliance rules (regulation)
 - KYC (know your customer)
 - AML (anti-money laundering)
 - CFT (combat the financing of terrorism)
- Customer has no privacy to service provider
 - Service provider knows real identity and full account/transaction information of customer
- Opaque, siloed databases and applications
- Need to be trusted to operate correctly and securely



Bitcoin: Birth of (Public) Blockchain

Bitcoin P2P e-cash paper

Satoshi Nakamoto | Sat, 01 Nov 2008 16:16:33 -0700

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

The paper is available at:

<http://www.bitcoin.org/bitcoin.pdf>

The main properties:

Double-spending is prevented with a peer-to-peer network.

No mint or other trusted parties.

Participants can be anonymous.

New coins are made from Hashcash style proof-of-work.

The proof-of-work for new coin generation also powers the network to prevent double-spending.

Bitcoin: A Peer-to-Peer Electronic Cash System

Satoshi Nakamoto
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www.bitcoin.org

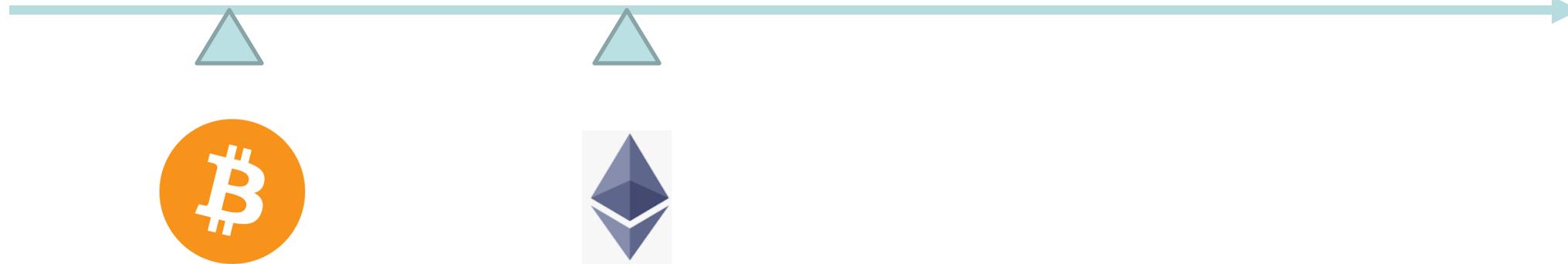
Abstract. A purely peer-to-peer version of electronic cash would allow online payments to be sent directly from one party to another without going through a financial institution. Digital signatures provide part of the solution, but the main benefits are lost if a trusted third party is still required to prevent double-spending. We propose a solution to the double-spending problem using a peer-to-peer network. The network timestamps transactions by hashing them into an ongoing chain of

Ethereum: Birth of Smart Contract Platform



Self-custody
of money

Programmable money
& financial asset



What is Decentralized Finance (DeFi)?

- Financial infrastructure as an open, permissionless, and highly interoperable protocol stack built on public smart contract platforms

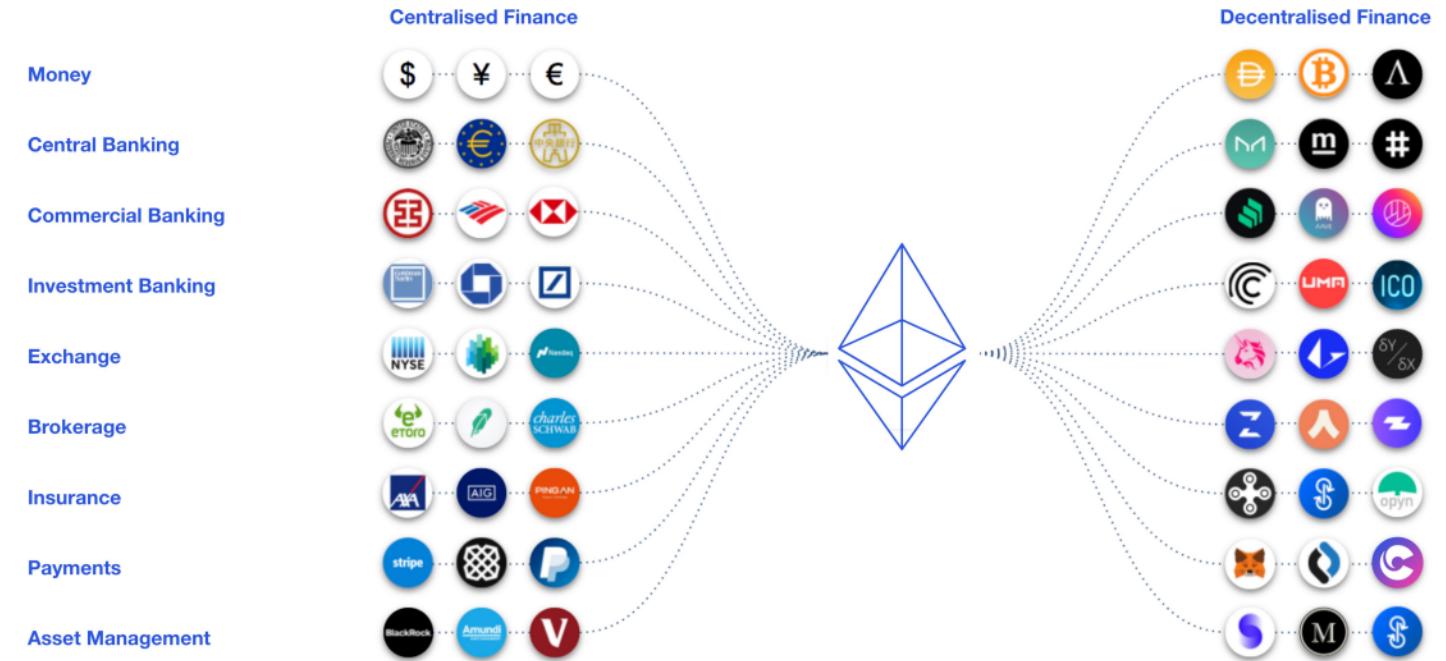
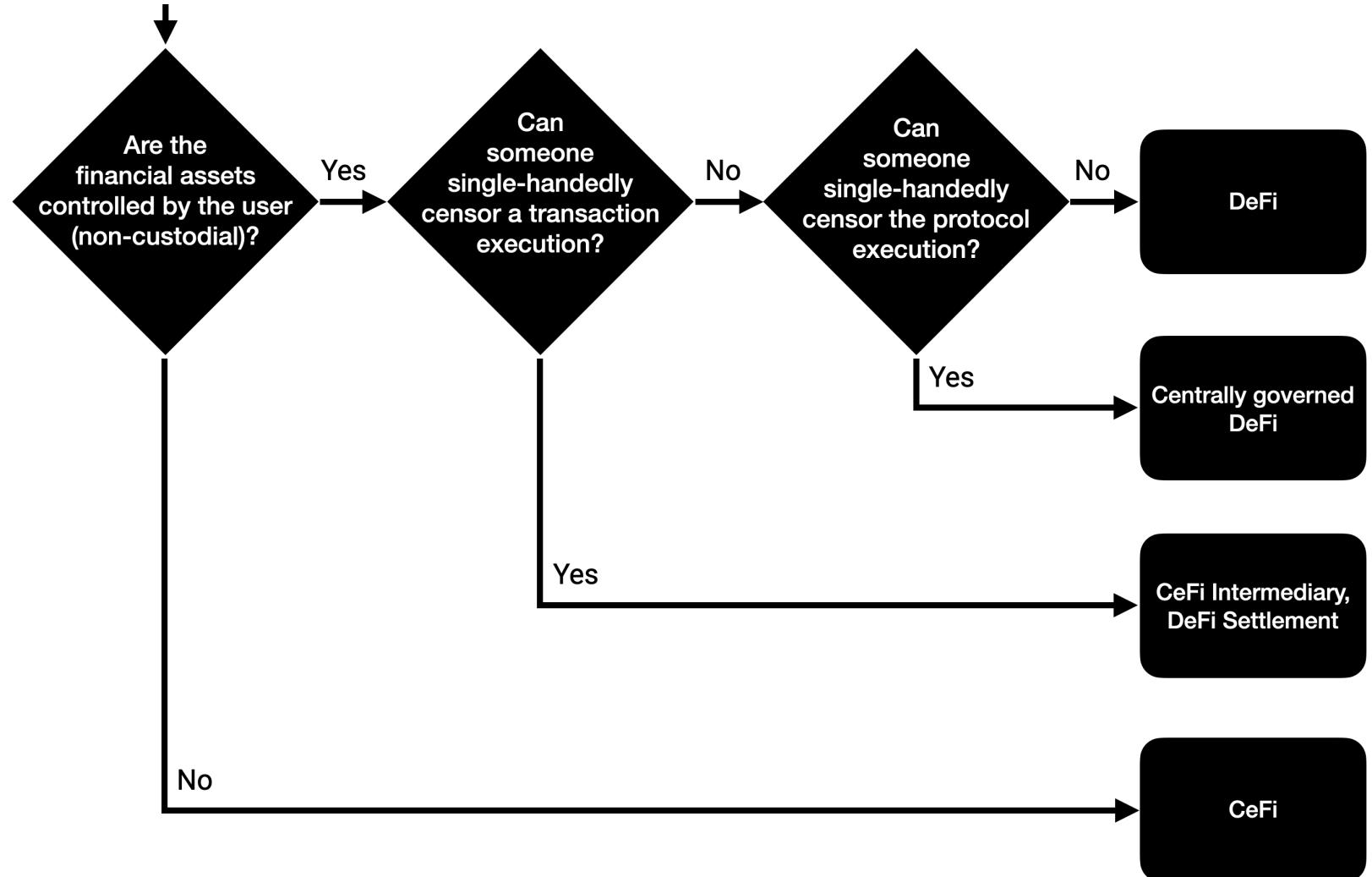


Image credit: Consensys Codefi

What is Decentralized Finance?

- Custody & settlement
- Transaction execution
- Protocol governance





Why DeFi?

CeFi vs. DeFi

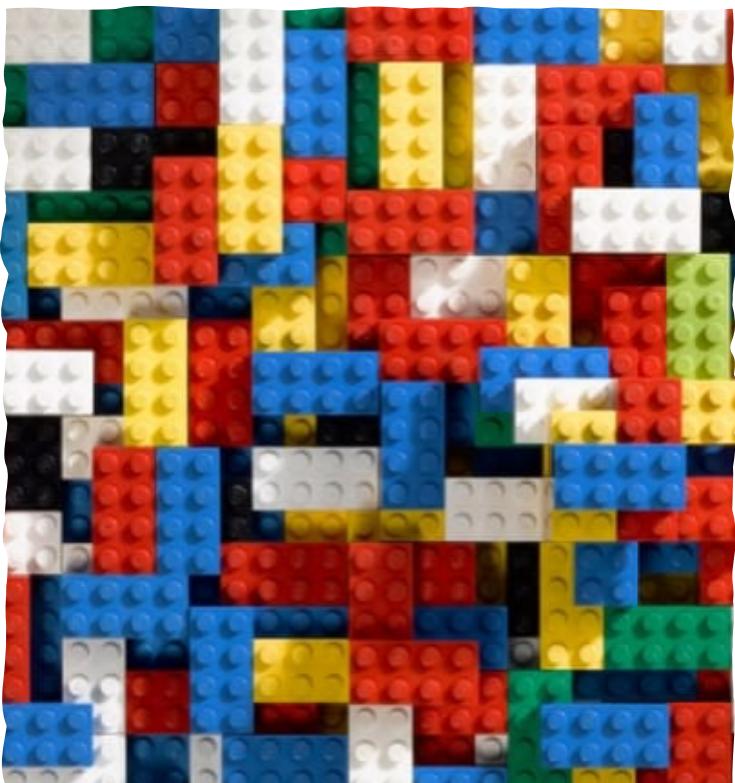
Traditional finance (CeFi)

- **Permissioned**
 - Closed-source system, built on top of centralized databases
 - Needs approval & agreement for third-party to use & build on
- **Custodial**
 - Assets are custodied by licensed third-parties
- **Centralized trust & governance**
 - Single entity responsible for upgrade decisions & admin privileges
- **Real identity**
 - Users register with real identity, e.g., for KYC/AML compliance

Decentralized finance (DeFi)

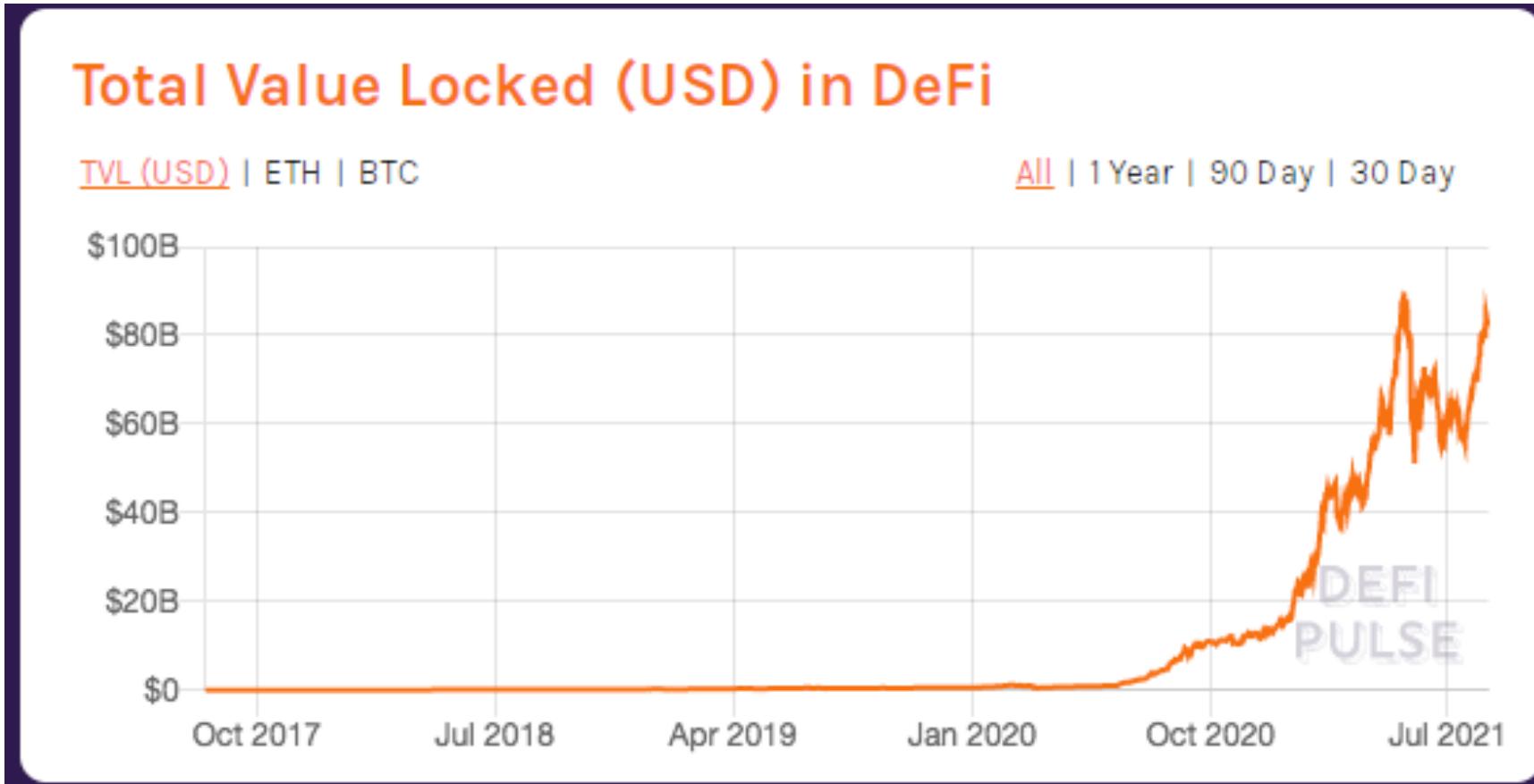
- **Permissionless**
 - Open-source system; built on top of permissionless blockchains
 - Anyone can use/ interoperate or build on top without third-party approval & agreement
- **Non-custodial**
 - Assets are not custodied by a single third-party
- **Decentralized trust & governance; Trustless**
 - No single entity responsible for upgrade decisions & admin privileges
- **Pseudonymous; privacy**
 - Users usually do not provide real identities

DeFi Advantages



- Efficiency
 - Removing rent-seeking intermediaries
- Open finance and universal accessibility
 - Inclusive
- Transparency and public verifiability
 - Anyone can inspect the smart contract code and verify the execution and state of the system
- Self custody and censorship resistant
- Automation & programmability
- Composability and interoperability
- Innovation
 - DeFi applications often are much simpler and faster to develop than CeFi counterparts
 - E.g., Uniswap vs. CEX
 - Atomic composability
 - E.g., Flash loan

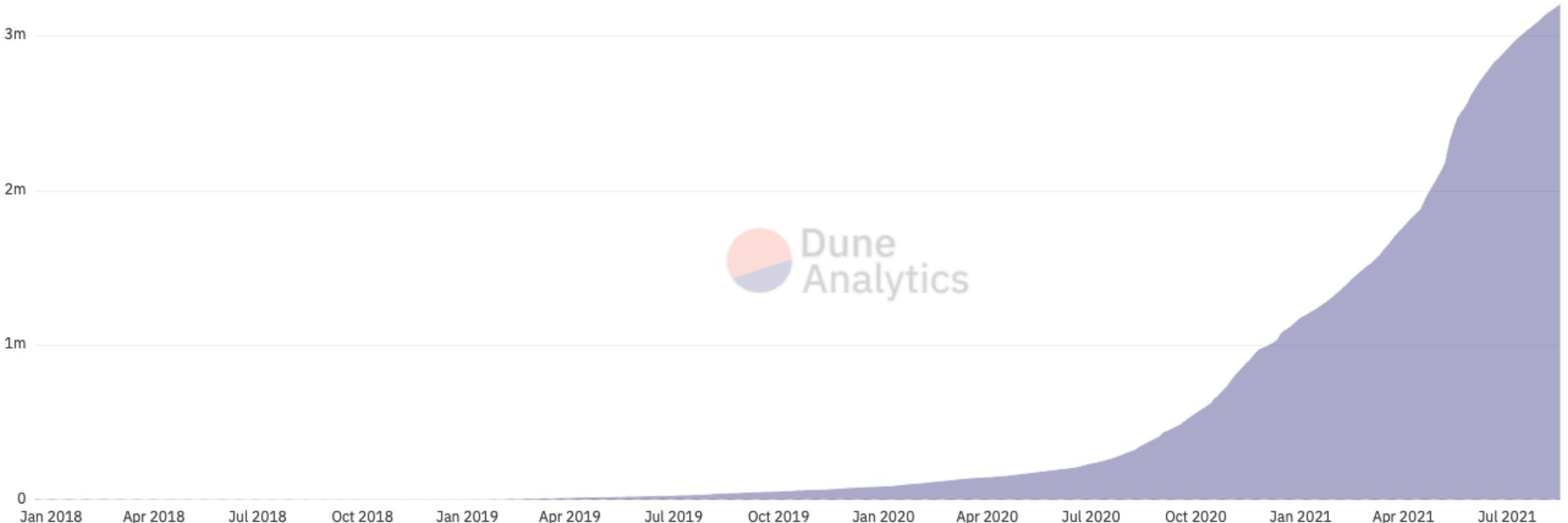
Fast Growth



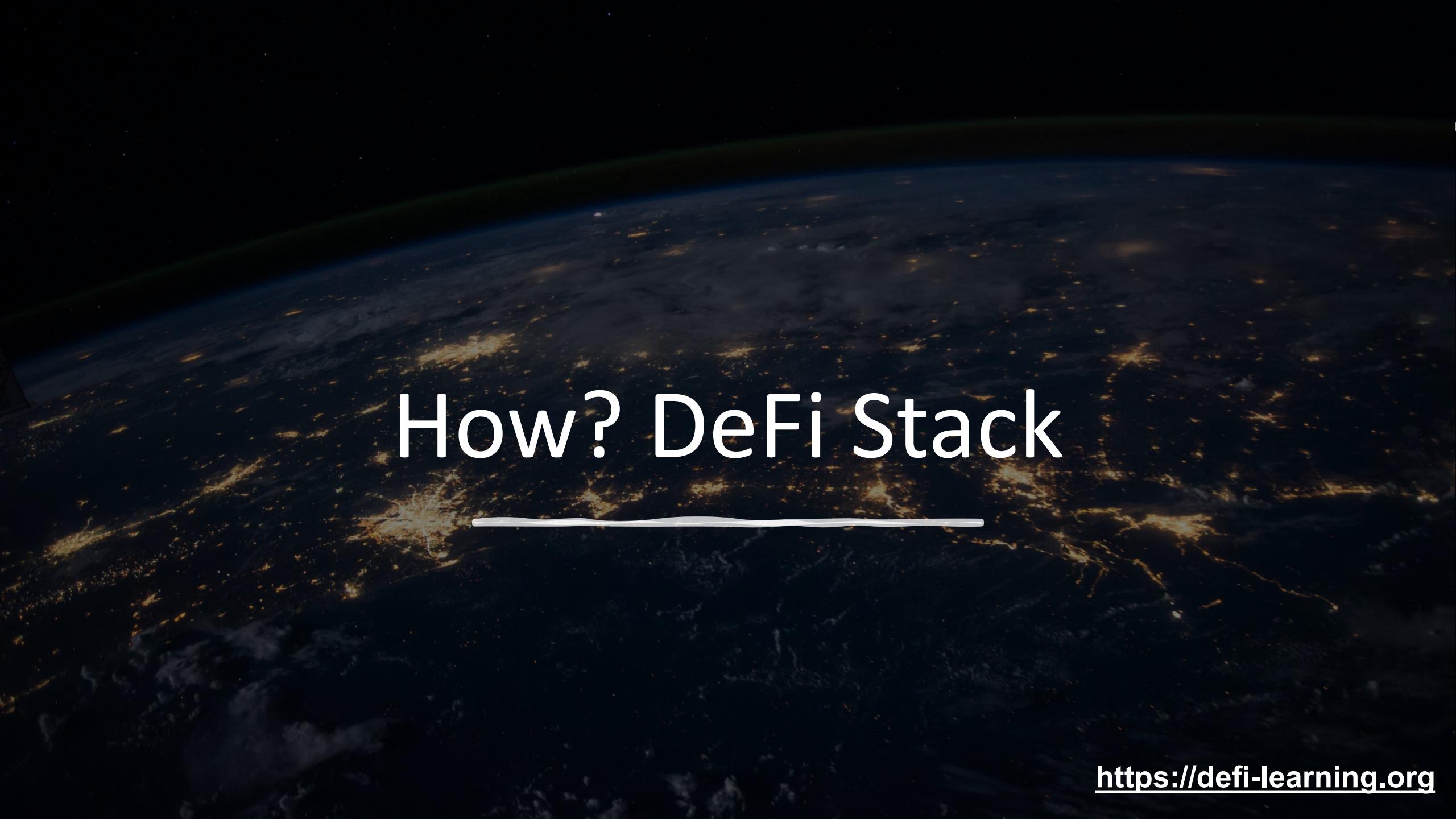
Fast Growth

Total DeFi users over time

Users = unique addresses. Since a user can have multiple addresses the numbers below are overestimates. Source: @richardchen39



[source](#)



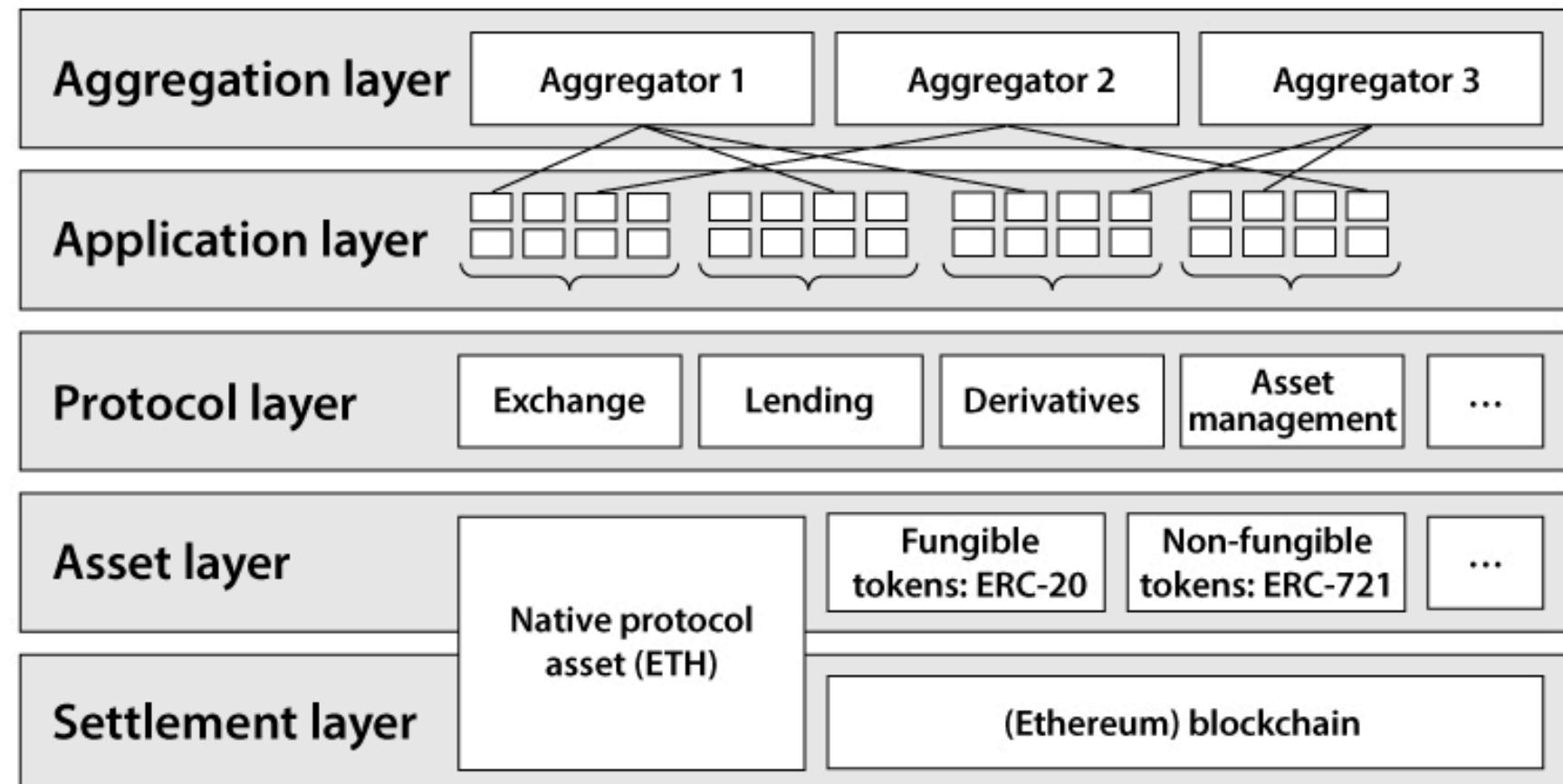
How? DeFi Stack

DeFi Stack

- DeFi is enabled by a decentralized smart contract platform

- Roles

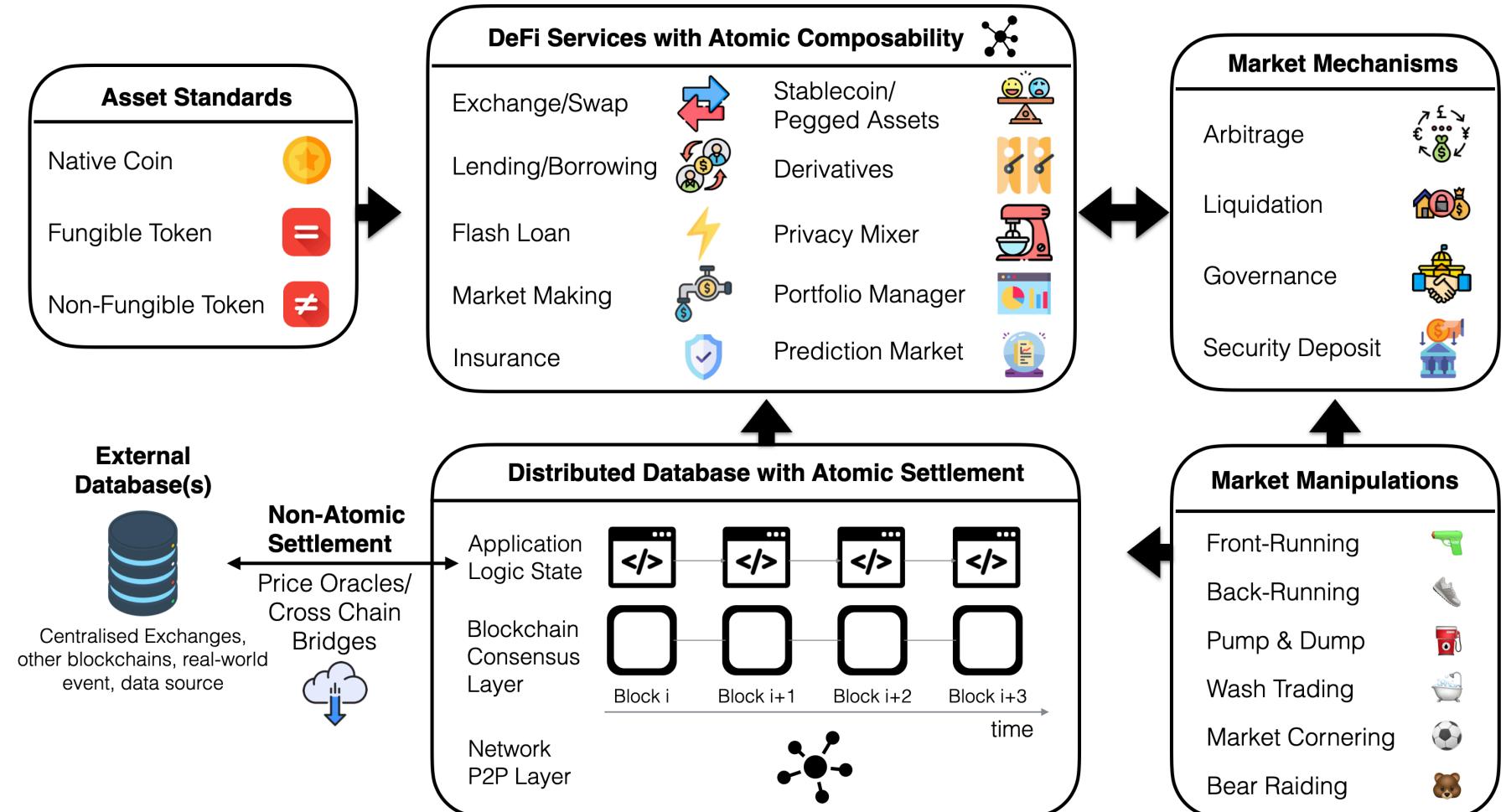
- User
- Protocol (smart contract)
 - Governance



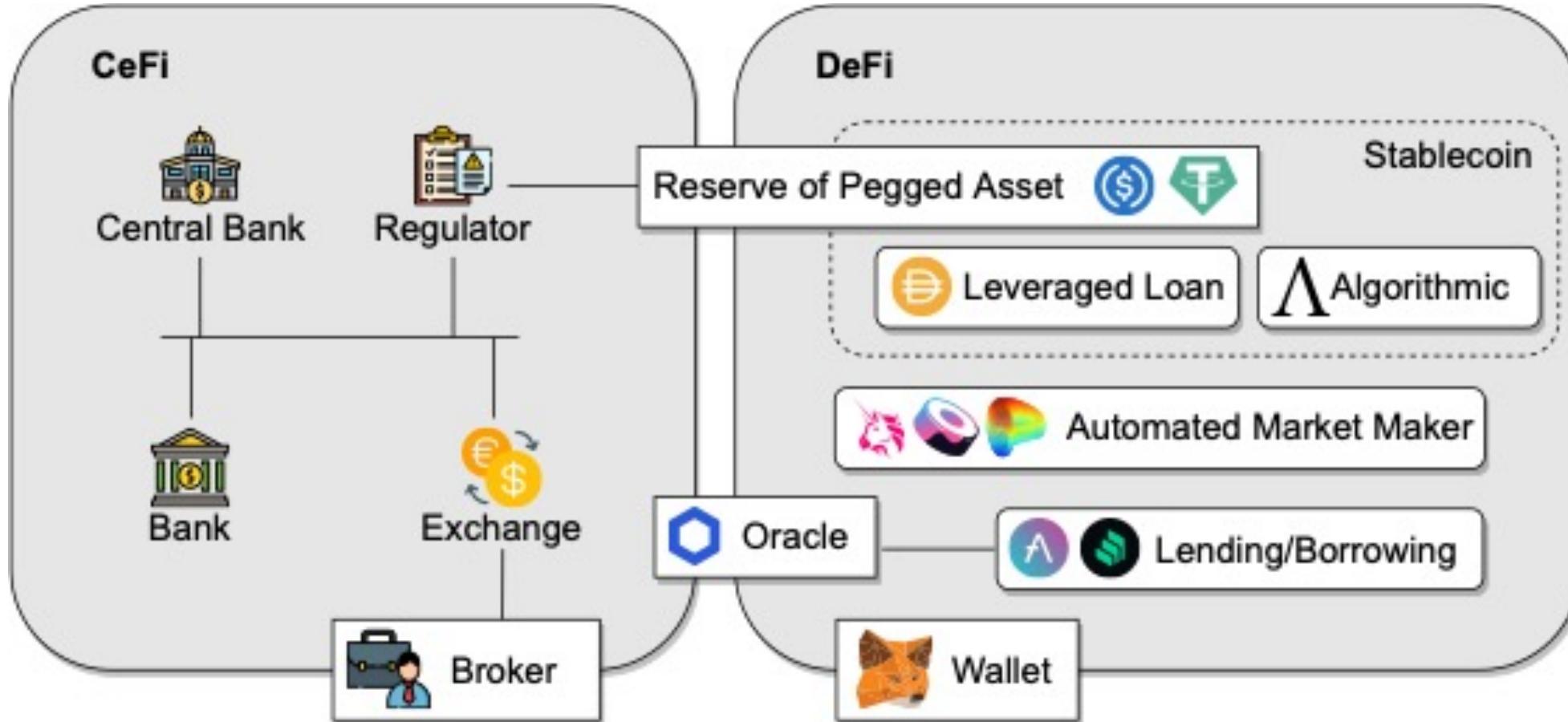
DeFi Stack

■ Roles

- User
- Protocol
- Keeper
- Oracle
- Bridge



High-Level Service Architecture of CeFi, DeFi

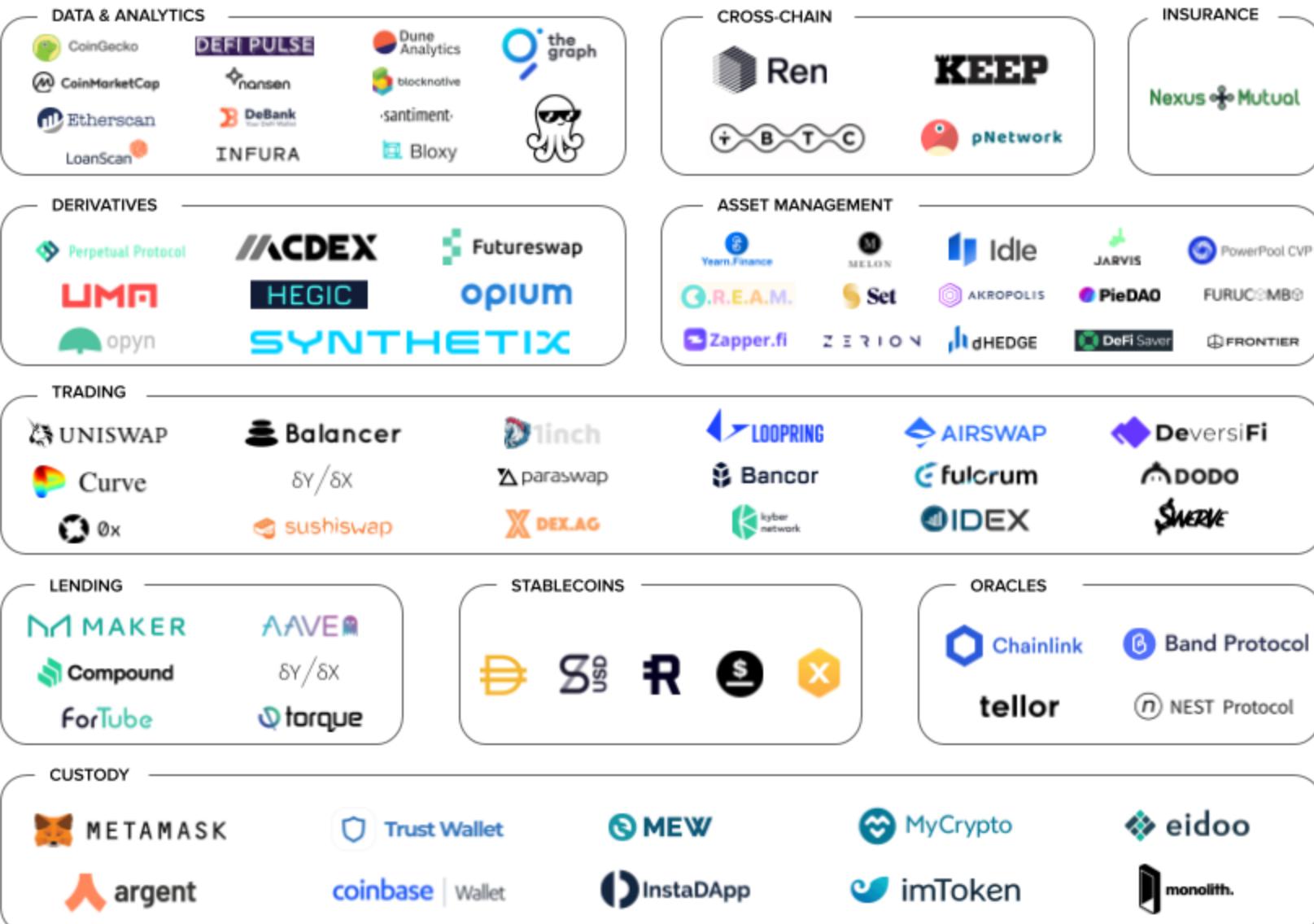


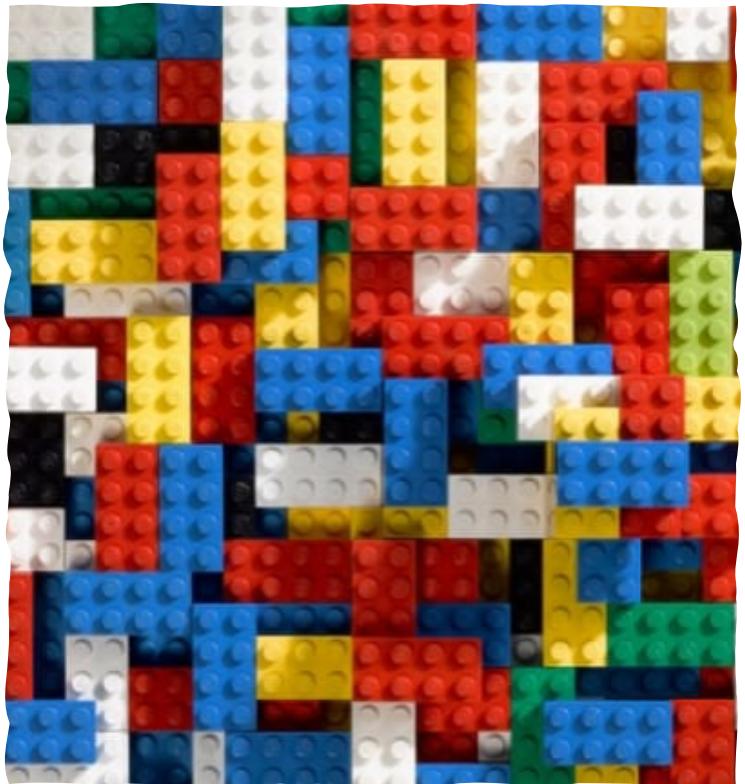
A nighttime satellite view of Earth from space, showing city lights and auroras.

DeFi Services and Innovations

<https://defi-learning.org>

ETHEREUM DeFi Map



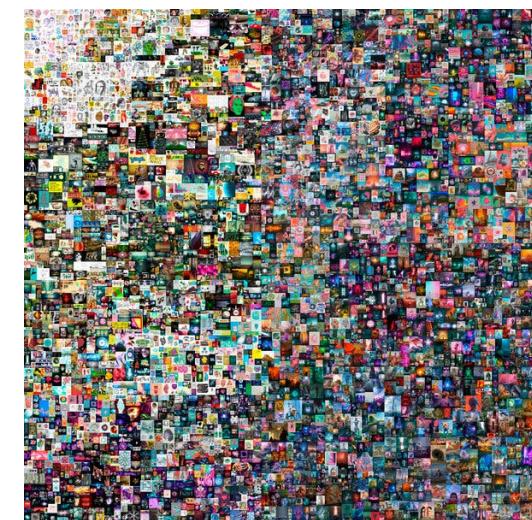
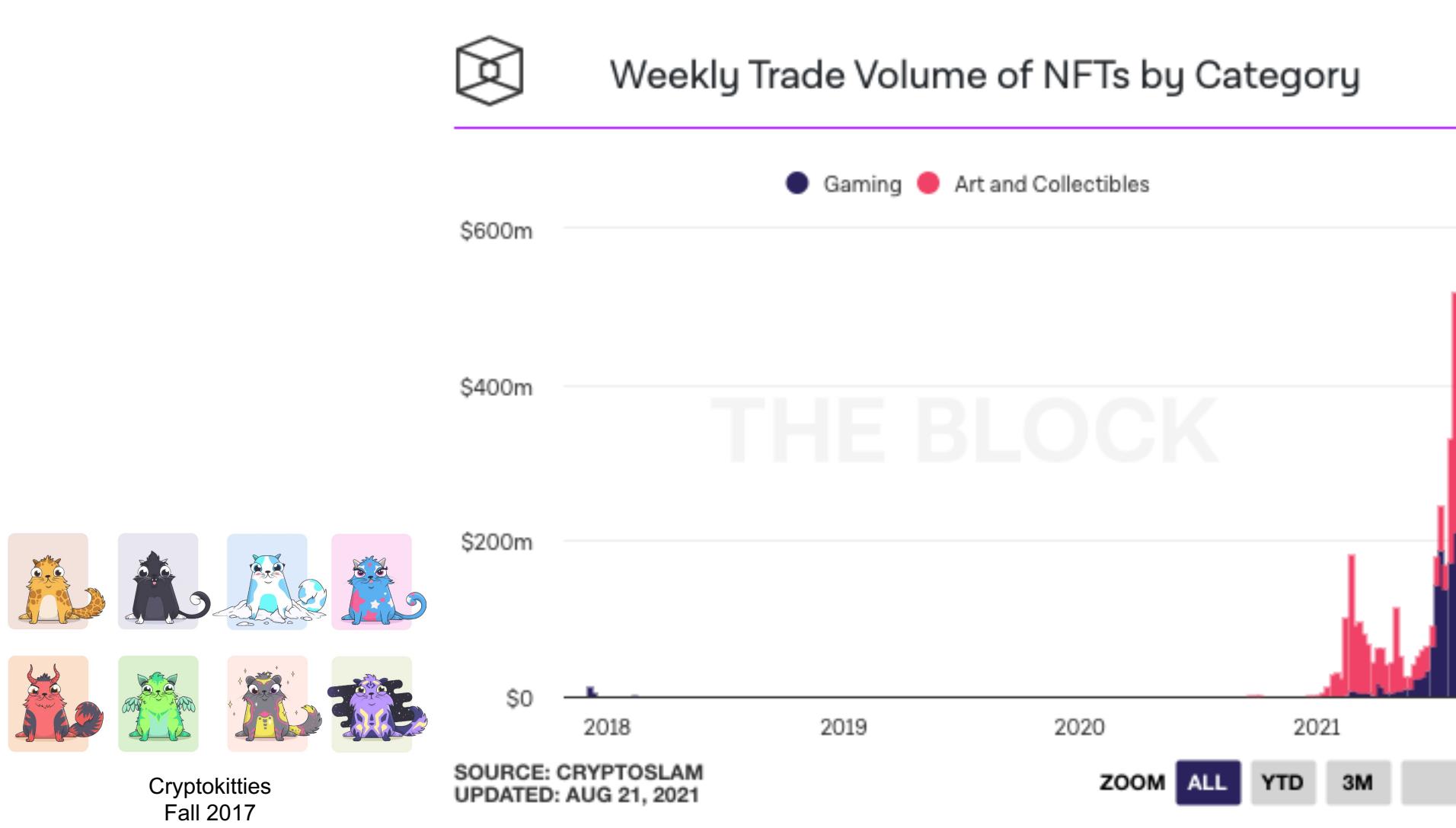


DeFi Building Blocks and Services (I): Asset Tokenization

Asset Tokenization

- Tokenization: process of adding new assets to a blockchain
- Token: the blockchain representation of the asset
- Make assets more accessible, easy to transfer, programmable
- Governance token, security tokens (tokenized real estate), Non-fungible token (NFT), stablecoin

NFT



Stablecoin

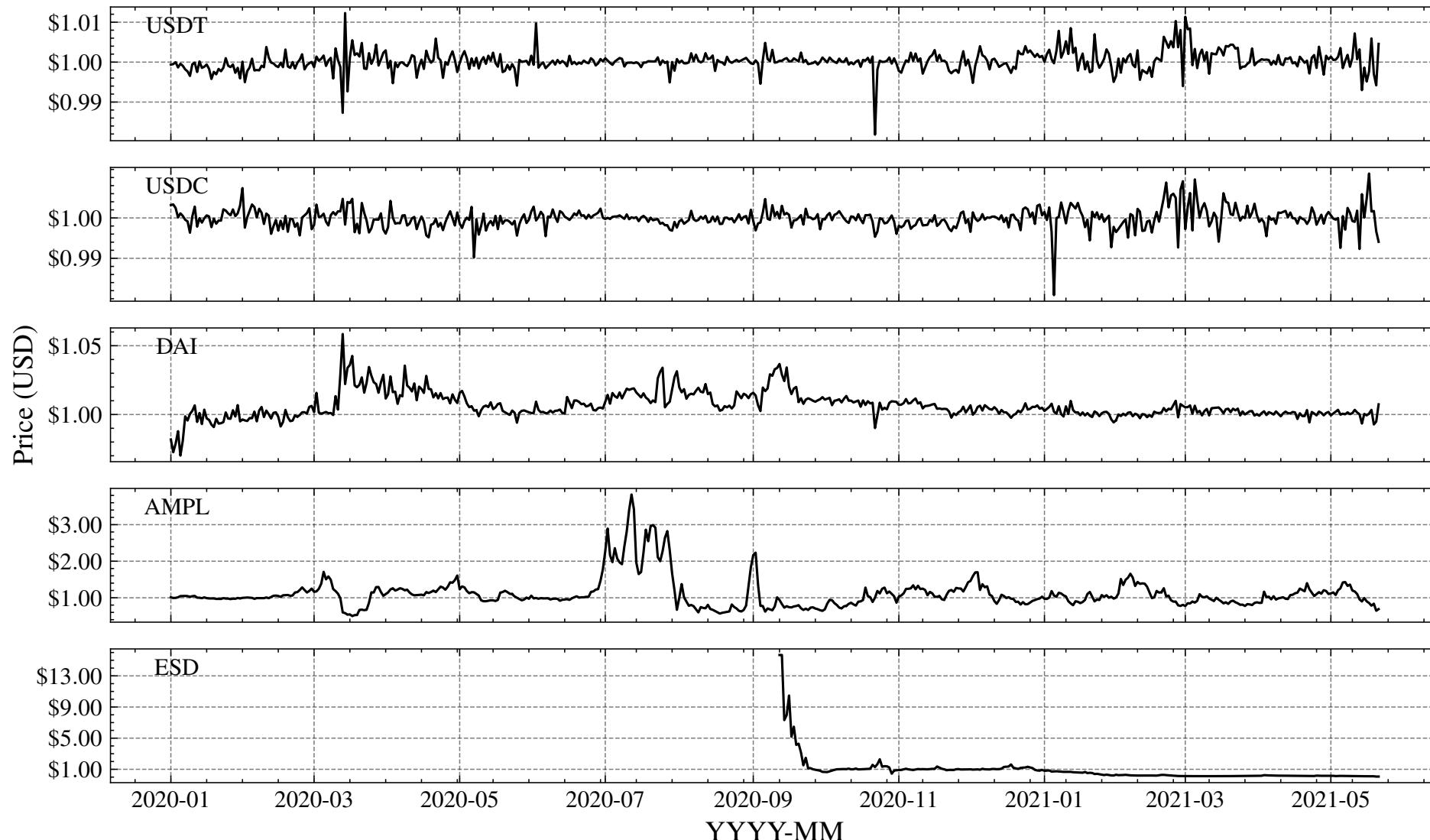
- Offchain (centralized) collateral [fiat, precious metal]
- Onchain (decentralized) collateral [crypto assets]
- Algorithmic (non-collateral) stable coin

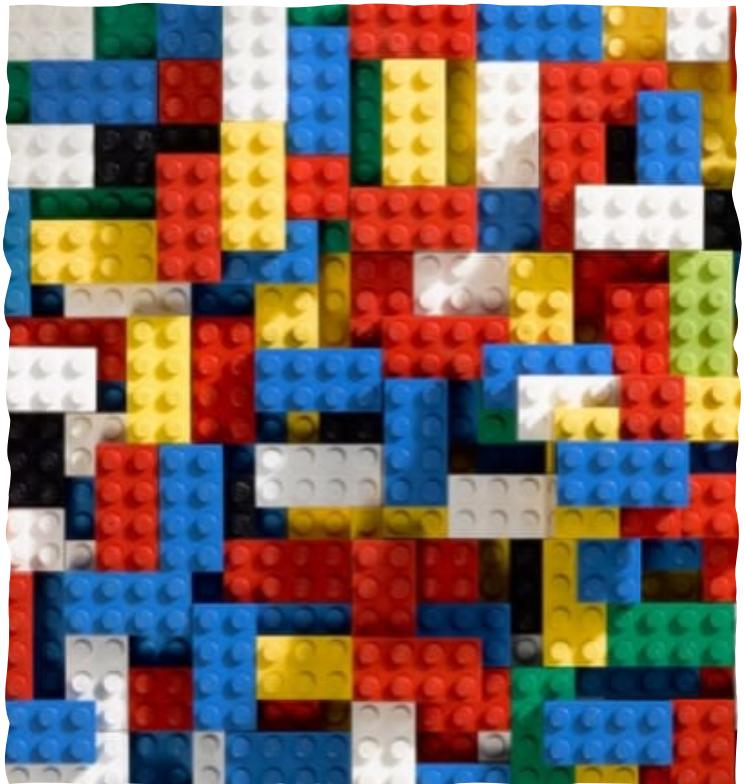
CURRENCY	MARKET CAPITALIZATION	COLLATERAL TYPE
Tether	\$64,209,563,142	Fiat
USD Coin	\$27,450,355,929	Fiat
Binance USD	\$11,923,057,774	Fiat
Dai	\$5,724,814,479	Crypto
TrueUSD	\$1,292,072,149	Fiat
Paxos Standard	\$944,424,017	Fiat
HUSD	\$489,713,563	Fiat
PAX Gold	\$318,754,237	Precious metals
sUSD	\$310,485,789	Crypto
Gemini Dollar	\$253,561,503	Fiat

Aug 2021

[source](#)

Stablecoin (In-)stability

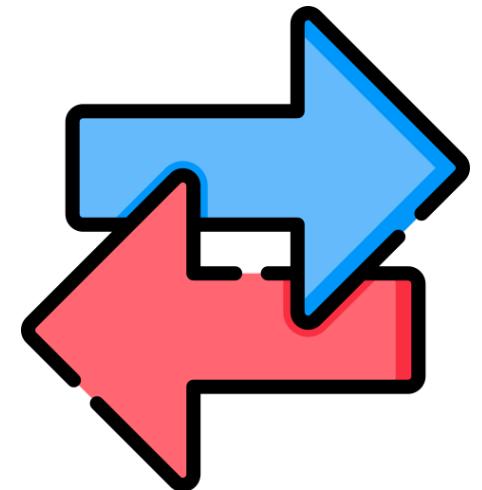




DeFi Building Blocks and Services (II): Decentralized Exchange

DEX vs. CEX

- Centralized exchange (CEX)
 - Custodial
 - attacks on CEX
 - Mt. GOX (2014): over 800,000 bitcoins stolen (over \$450M at the time, over \$30B currently)
 - 2019: over 12 CEXes attacked, \$300M crypto stolen
 - Rogue CEX
 - Non-transparency
- Decentralized exchange (DEX)
 - Non-custodial
 - Transparency



DEX vs. CEX

- CEX:
 - Order book
- DEX:

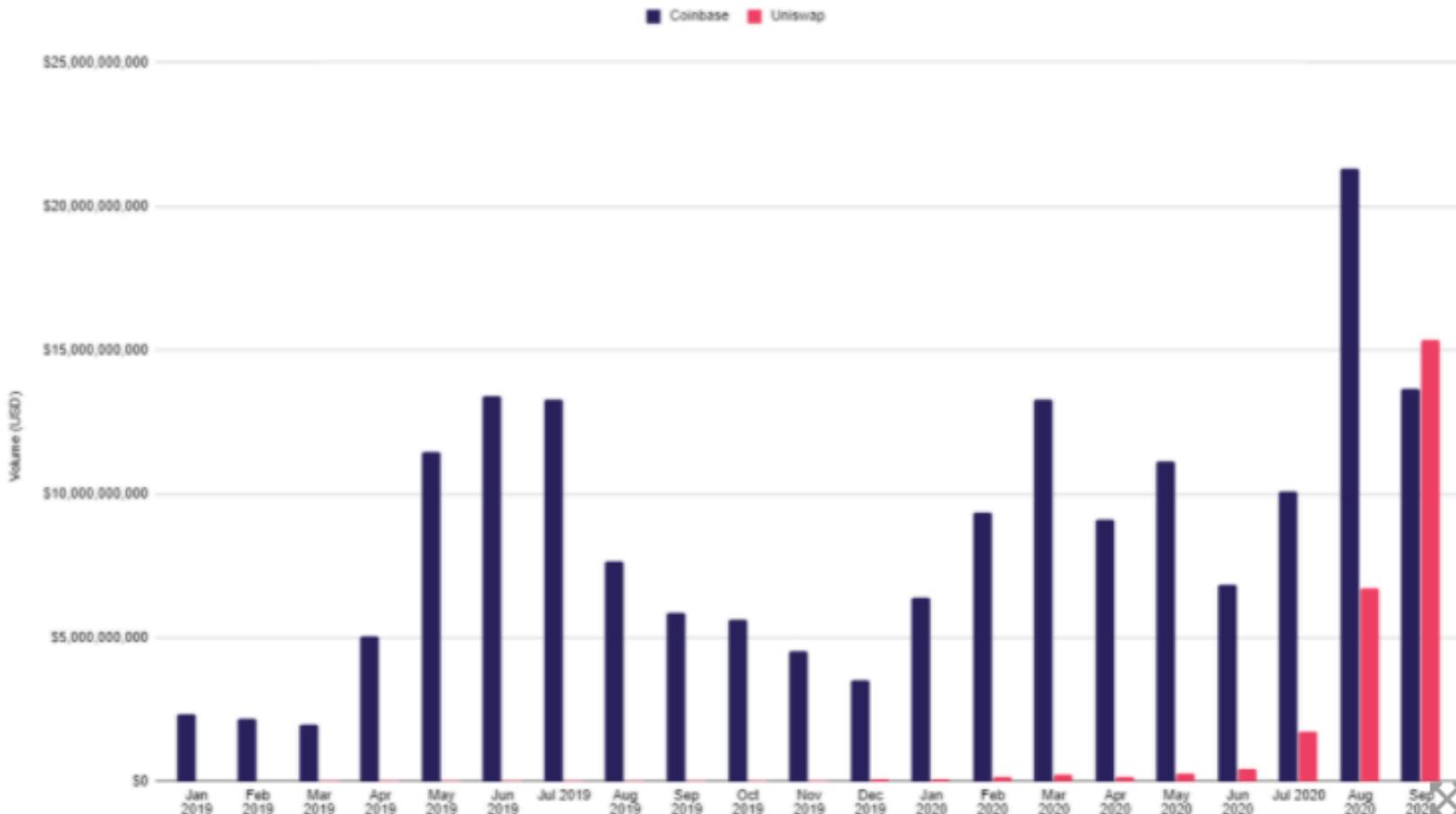
Protocol name	Protocol type	Price discovery
0x	Exchange	Off-chain order books
(Air)Swap	P2P / OTC	P2P negotiation
Bancor	CFMM	Smart contract
Balancer	CFMM	Smart contract
Curve	CFMM	Smart contract
Kyber Network	Reserve aggregator	Proposal by maker
UniSwap	CFMM	Smart contract

NOTE: CFMM, constant function market maker.

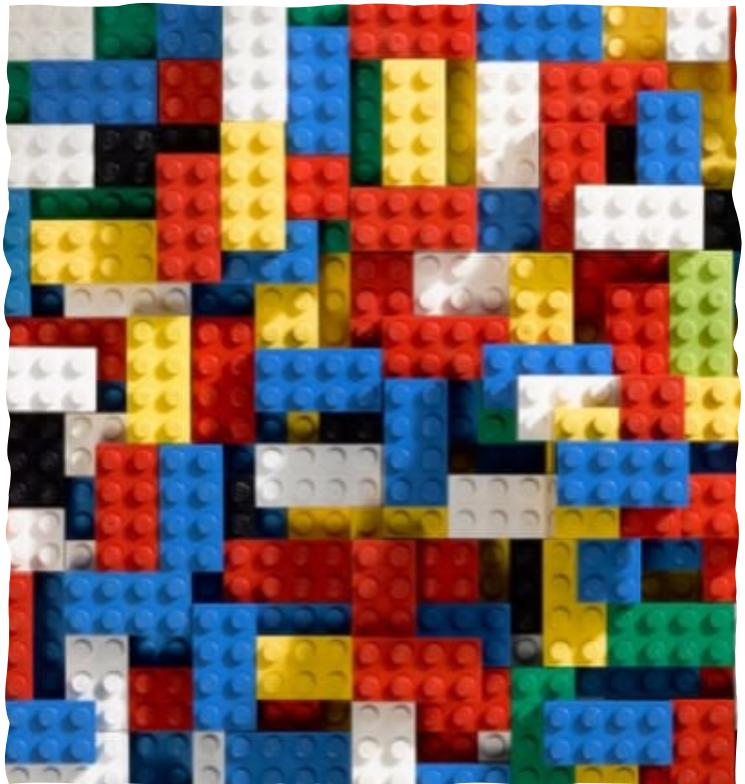
DEX vs. CEX

THE BLOCK | Research

Coinbase vs. Uniswap, Monthly Trade Volume



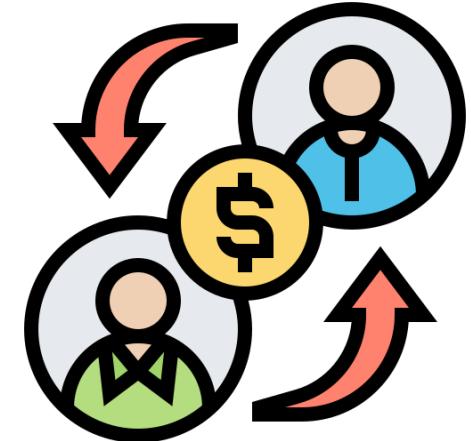
Source: Dune Analytics, CryptoCompare



DeFi Building Blocks and Services (III): Decentralized Lending

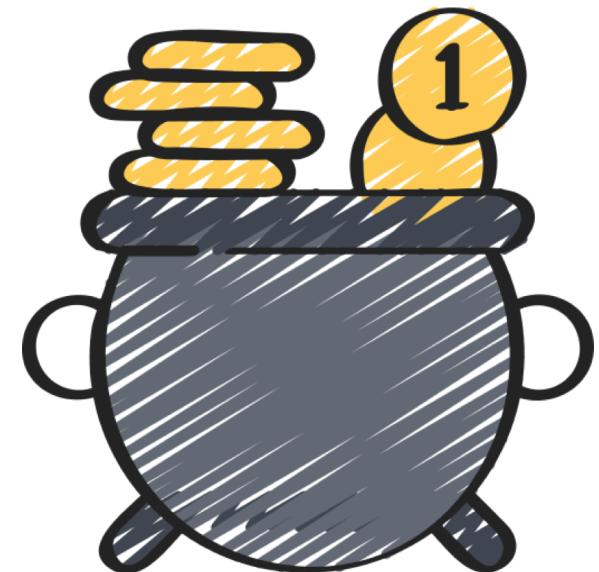
Decentralized Lending

- Lending in CeFi:
 - Processing default is expensive; under-collateralization
 - Credit-worthiness
- Collateralized loans in DeFi
 - Over collateralization; not based on credit
 - Collateralized debt positions: creating new tokens using collateral
 - E.g., MakerDAO
 - Collateralized debt markets:
 - Pooled collateralized debt markets: e.g., Compound, Aave
 - P2P collateralized debt markets
 - Under collateralization

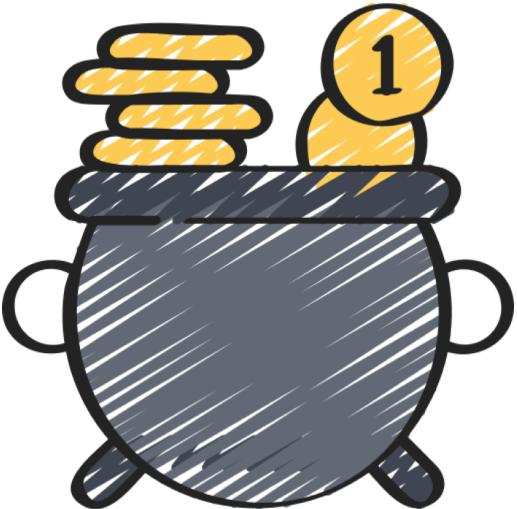


Flash Loans

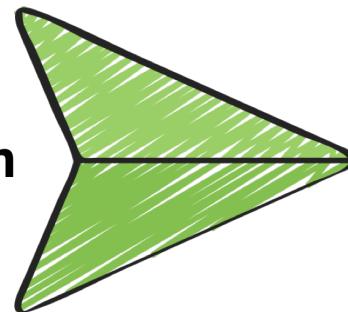
- Blockchains enable *atomic* transactions
 - The actions within a transaction are *executed entirely in sequence*, or *fail collectively*
- Pools lend assets within one transaction
 - Under the condition that the assets
 - are paid back by the end of the transaction
 - plus interests on the lent amounts
 - Can grow to Billions of USD
 - without upfront costs (only transaction fees)
- Does not exist in CeFi!



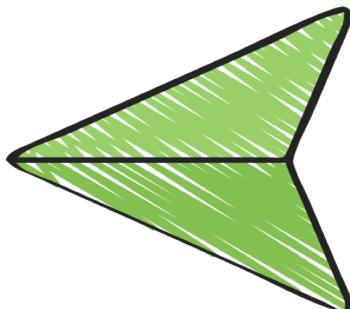
Flash Loans



1. Take flash loan

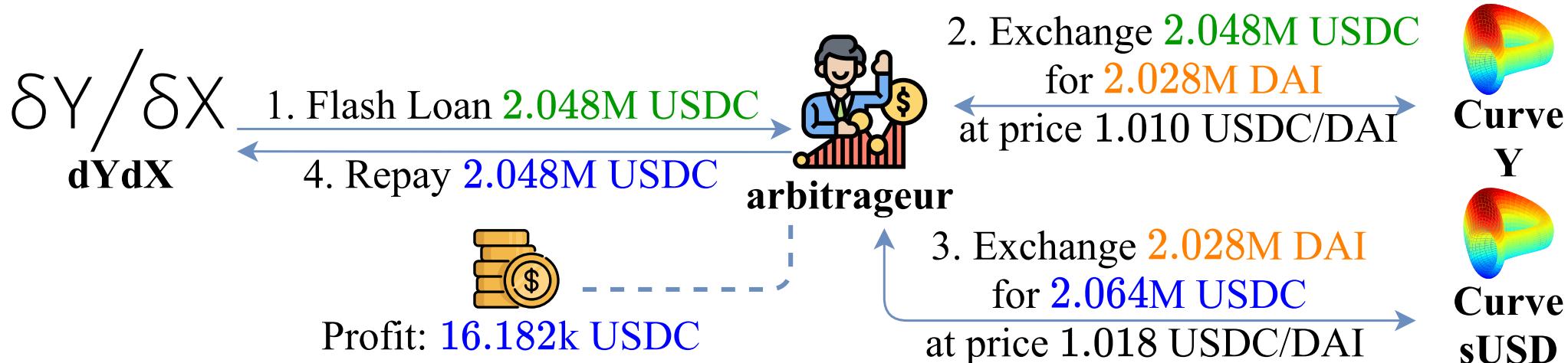


2. go-Wild(loan);



3. Repay loan + interest

Flash Loan Example



Other DeFi Building Blocks and Services

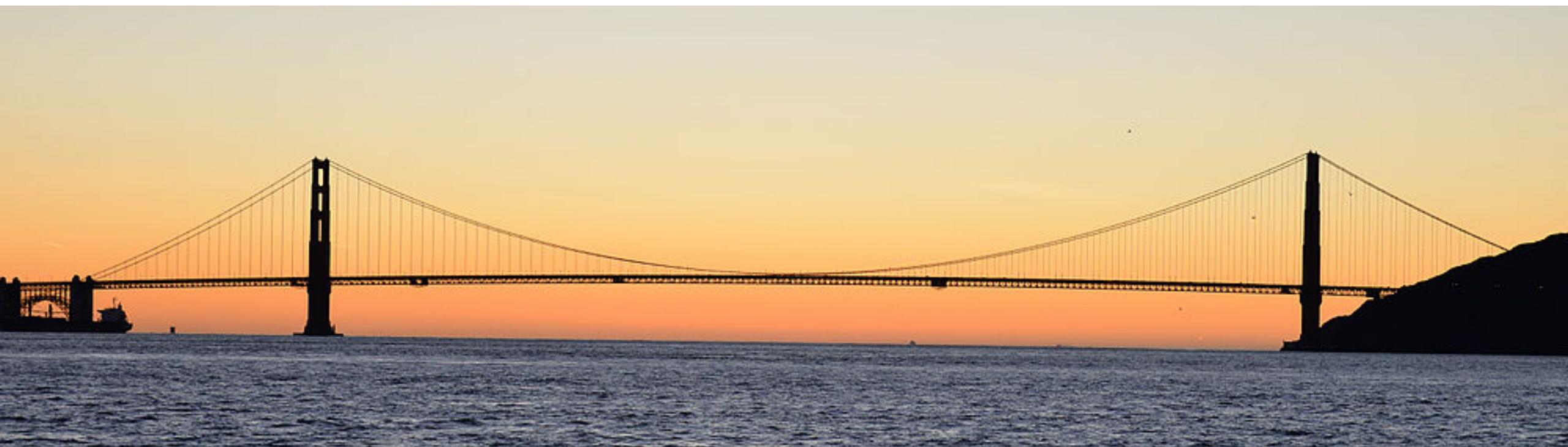
- Decentralized derivatives
 - Asset-based derivatives: e.g., Synthetix, Mirror
 - Event-based derivatives: e.g., Augur
- On-chain asset management
 - Non-custodial, different from traditional asset management
 - Semi-automatic rebalancing of portfolio, trend trading
 - E.g., Yearn, Set protocol
- Decentralized insurance





Risks in DeFi

DeFi Security



DeFi Security - Issues on all Layers

- Network attacks
 - Eclipse/Dos attacks
- Consensus attacks
 - 51% attacks/Double-spending/Selfish mining
- Smart Contract code bugs
 - Reentrancy/Authorization/etc
- DeFi Protocol Composability attacks
 - Excessive arbitrage between pools, flash loans
 - Oracle attacks
- Bridge attacks
- Governance attacks



DeFi attacks stole over \$1B in 2021

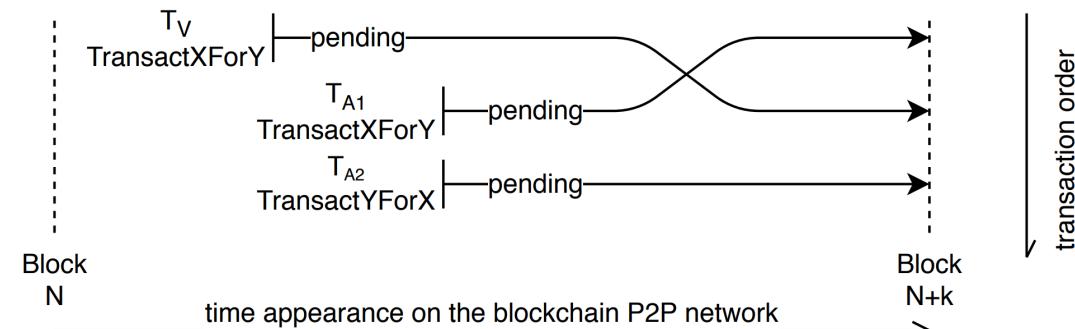
DeFi Security

- **Technical structure security**
 - Risk-free profit by exploiting technical structure of blockchain systems
- **Economic incentive security**
 - Exploit the incentive structure of the protocol to realize unintended profit at the expense of the protocol or its users

Front-running Attacks

1. Adversary (\mathcal{A}) observes a transaction T on the blockchain P2P network
2. \mathcal{A} creates a transaction T_2 that pays a higher transaction fee (gas)
3. Miners mine transactions based on their paid fee, execute T_2 before T
4. Same technique can be used to back-run a transaction

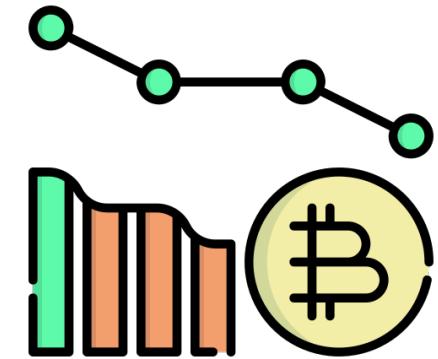
→ Sandwich attacks 



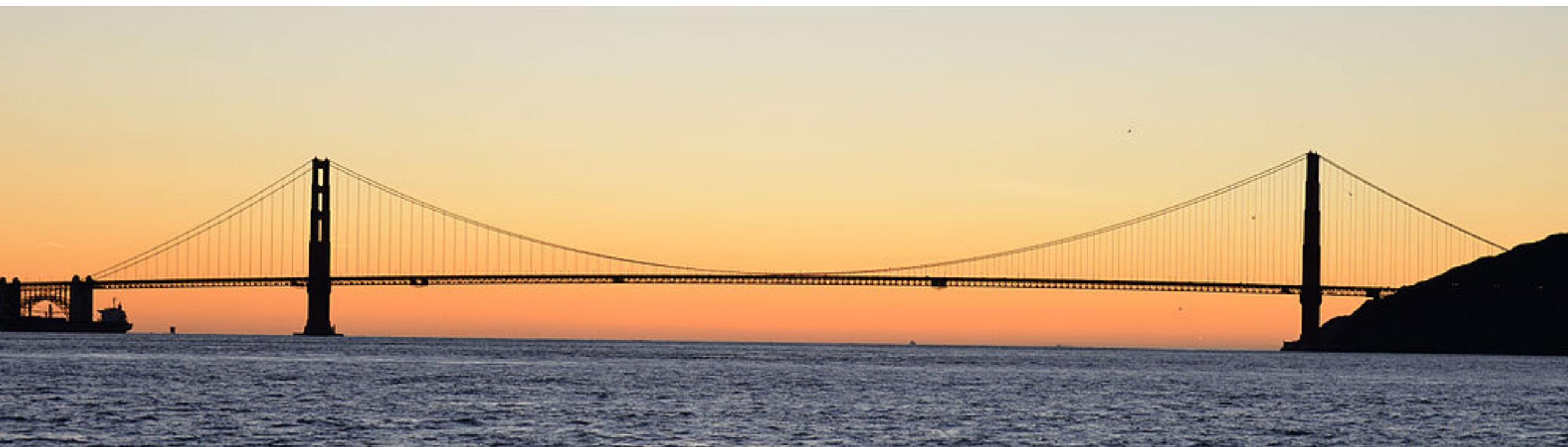
Miner Extractable Value (MEV)

DeFi Dependencies & Systemic Risks

- Multiple significant price declines in cryptocurrencies
 - -30% on the 12th of March 2020
 - -40% on the 19th of May 2021
- Causing ripple effects
 - Liquidation
 - De-leveraging
- Stock markets have circuit breakers to stop losses
- Transaction fees on blockchains spiked, a regular coin transfer costed over 100 USD



DeFi Privacy



Privacy in DeFi

- Blockchains with DeFi are mostly pseudonymous, not anonymous.
- Balances, transactions, timestamps, amounts are all public.
- See the many super-wealthy DeFi accounts for yourself..



(Non-existent) Privacy in DeFi

The screenshot shows a DeFi wallet profile on the DeBank platform. The profile page displays the address 0x3ddfa8ec3052539b6c9549f12cea2c295cff5296, which has been active for 82 days. The user has 0 Following and 90 Followers. The total value of assets is \$4,114,352,459, with a recent change of +\$311,434. The profile includes tabs for Portfolio, History, and Approval, with Portfolio being the active tab. It also shows asset distribution across All Chains (Ethereum, BSC, xDai, Polygon, Fantom, OKExChain, HECO). A callout bubble highlights the total value of \$4B USD and the daily increase of +300k USD/24h.

Full breakdown of how many assets in which token and DeFi platform.

Yes, 4B USD, and +300k USD/24h

2.9B on Ethereum, 1.1B on BSC

ASSET	PRICE	BALANCE	VALUE
COMP	\$376.26	39,377.1714	\$14,816,077

A nighttime satellite view of Earth from space, showing city lights and auroras.

Open Research Challenges

Open Research Challenges

- Scalability
- Universal accessibility; usability
- Privacy (privacy with compliance)
- Security
 - Oracle
 - Program/protocol analysis and verification
 - Protocol security
 - Smart contract security
 - Composability risks/systemic risks
 - Incentive design
 - Miner extractable value
 - Governance
- Legal framework

Interdisciplinary Research

- Explore open questions in DeFi
 - For each financial function, investigating CeFi & DeFi options:
Is either one of these optimal? We will evaluate both through the lens of CS and finance. Is the application computable (efficiency, decidable), programmable (automatic)? Is the application welfare-enhancing and stable (not a source of systemic risk). How do the new and old systems interact?
- Intersection of Finance & Computer Science
 - Investigate through both lenses
- New questions and challenges in regulation and legal frameworks

Course Syllabus

Date	Topic
08/26	Introduction and Overview of DeFi
09/02	Introduction to Blockchain Technology
09/09	Introduction to Smart Contracts
09/16	Introduction to Traditional Finance
09/23	Stablecoins
09/30	DEX
10/07	Decentralized Lending
10/14	Synthetic And Derivatives; Portfolio Management; Insurance; Information and Data Markets
10/21	Oracles
10/28	Privacy in DeFi; Auditable Privacy; ZKP
11/04	Decentralized Identities
11/11	No Class (Veterans Day)
11/18	DeFi Security I
11/25	No Class (Thanksgiving)
12/02	DeFi Security II
12/09	Regulations and Legal Frameworks

References & Recommended Reading

- CeFi vs. DeFi — Comparing Centralized to Decentralized Finance, Qin et al.
- SoK: Decentralized Finance, Werner et al.
- Decentralized Finance: On Blockchain- and Smart Contract-Based Financial Markets, Fabian Schär.

