Is Ethereum Decentralized?

An interdisciplinary study of **social network analysis**, **agent-based modeling**, and **game theory in distributed systems.**

Requirements [URL]

Selection criteria

Surprise us with your creativity! But here are a few selection criteria considerations:

- Impact of the proposed research output.
- Quality of work and experience of the research team.
- Clarity, conciseness and organization of the proposal.
- Contribution to the wishlist areas.
- Potential of long-term involvement in the Ethereum ecosystem.
- Analyses or visualizations that help a non-technical audience gain insight into the research.

Wishlist

The Ethereum Foundation is interested in research and academic output in the following domain areas, but don't let this restrict your creativity. Check out our **wishlist**.

applications for any academic projects that relate to Ethereum.

- 2022 EF Academic Grants Round
  - Domains
    - Economics
    - Consensus/Protocol
    - Formal Verification
    - MEV
    - Cryptography
    - P2P networking
    - Hardware

Domains

Economics

- Rollup economics: incentives for decentralised sequencers, risk management for bridges/rollup operators, congestion/resource pricing, decentralised markets for fraud proofs/validity proofs.
  - Understanding rollup economics from first principles
  - MEV Auction: Auctioning transaction ordering rights as a solution to Miner Extractable Value
  - Spam resistant block creator selection via burn auction
  - Against PoS for rollup leader election

Project Proposal

Project name: Is Ethereum decentralized?

Brief project summary:

Background

The blockchain technology has gain great advantages based on its achieved consensus in a decentralized system and innovation in the traditionally trusted institution-relied industy - the key feature of decentralization (Gencer et al. 2018). Decentralization empowers the operation and uniqueness of blockchain platforms and services, makes them prospective in the future.

Ethereum is a decentralized blockchain platform that establishes a peer-to-peer network that securely executes and verifies application code for disseminating block and transaction information (Wood 2014).
Bitcoin (Nakamoto 2008) and Ethereum (Wood 2014) platform account for over 70% of the cryptocurrency market on blockchain. Bitcoin and Ethereum possess a peer-to-peer network for disseminating block and transaction information. Major techiniqus to study decentralization usually includes Social Network Analysis (SNA) and mechanism design (Mookherjee 2006) and theory modelling (Malamud and Rostek 2017). However, current study on decentralization tends to neglect 1) the impact of incentives on agent behavior network formation, and 2) the impact of incentive design on the final realizations of decentralization, and our study will innovate on methodology and contexts to solve these existing limitations.

To be more specific, our study will focus on the context of Ethereum 2.0. Ethereum 2.0 is an upgrade to the Ethereum blockchain. The upgrade aims to enhance the speed, efficiency, and scalability of the Ethereum network so that it can process more transactions and ease bottlenecks

(Millman 2020). However, similar to the study of Ethereum 1.0, there exists a lack of justification on the guarantee of decentralization in Ethereum 2.0, especially a lack of research in incentive designs that affect the stakeholders' behavior, network formation, and final realizations of decentralization. Based on the existing liteature, our study is aimed at figuring out:

Research Questions

1. How do incentives in Ethereum 2.0 Proof-of-Stake affect agents' behavior and network formations?
2. How does changing the incentive design in Proof-of-Stake affect the realization of network decentralization?

Methodology

1. **Empirical analysis of network dynamics**

An extensive literature explores the key features of trading networks and how they relate to the price dynamics of cryptocurrencies. The network structures differ significantly across blockchains.

Our study will conduct a comprehensive analysis of the Ethereum transaction network and the core-periphery structure by extracting network features including the numbers of nodes and edges, the mean and standard deviation of degree., top 10 degrees mean ratio, relative degree, modularity, the count of components, the count of core, and giant component ratio, etc. We will visualize the transaction network on Beacon Chain using network graphs (see Figure 1. For sample graph). After feature extraction, we will build time-seires plot to visualize the network dynamics. By conducting the core-periphery analysis, we will specifically investigate in cores that influences the network (i.e. centralized exchanges/smart contracts of major functions).

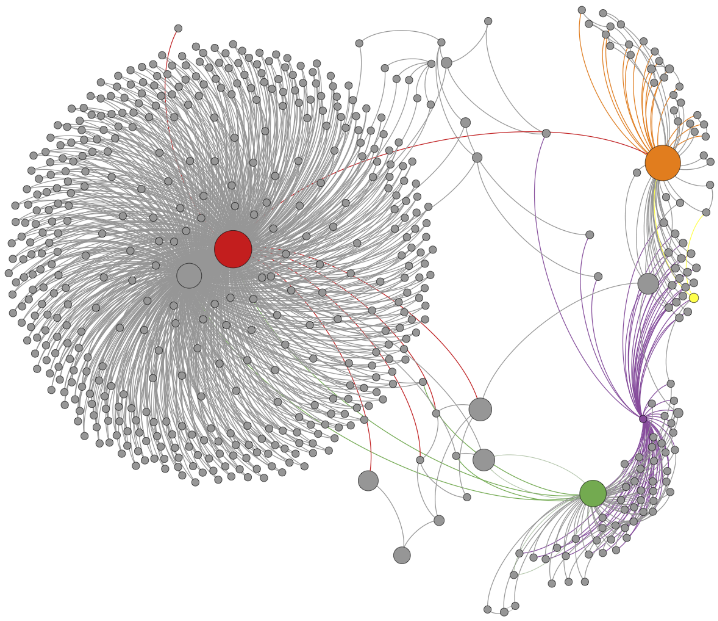

Figure 1. Network graph for Bitcoin transaction (Cornell 2014)

2. Modelling Network Formation - Game theory in distributed system

Game theory possesses great coordination and contagion in Social Networks (Cornell n.d.). Our study will apply network game theory to the Ethereum 2.0 distributed system to study the network formation in this system and how do incentives in Ethereum 2.0 Proof-of-Stake affect agents' behavior and network formations.

3. Simulate the network formation and estimate parameters with data - Multi-agents simulations

Our study will apply ABM combined with to simulate the Ethereum 2.0 Beacon Chain Network to demonstrate the effect of changing incentive design on the realization of decentralization and study the micro-interactions and behavior of different types of agents. Moreover, we will estimate how the designs of cores including centralized exchanges and smart contracts of majors functions would influence network formation and decentralization. Considering the characteristics of Ethereum 2.0 Beacon Chain Network 1) agents having clear objectives, 2) easy accessibility to the corresponding data, and 3) possibilities to make comparisons by controlling the conditions in agent-based experiments (LeBaron 2000), we believe ABM will be a good fit under this context.

In order to estimate, compare and evaluate the parameter setting of the proposed agent-based model, we will acquire the real data of transactions recorded on Ethereum 2.0, specifically data on beacon chain (Bitquery n.d.) under centrain blocks to verify our model and further find the optimal simulation that could explain the reality.

Potential Results

This study will produce:

PR1 (Answer to RQ1):
PR2 (Answer to RQ2):

1. Comprehensive network ananlysis of the Beacon chain transaction network, which includes network graph, network features metrics, time-series plots of network features, and core-periphery analysis results.
2. Network game theory model applied to the context of Ethereum 2.0 Proof-of-Stake incentive design, which gives the network formation on Ethereum and shows the affect of incentive design on the realization of network decentralization.
3. An muti-agent-based model for the Ethereum 2.0 Beacon Chain Network that simulates the incentive mechanism, agents' behaviors, and trading network structure formations, which will be estimated and evaluated with real data on Beacon chain.
4. Improvement suggestions for Ethereum 2.0 upgrades on its incentive design based on the theories and modeling results.

Intellectual Merits

Our research contribute to 3 lines of literature XXX, YYY, ZZZ.

1. **Social Network Study**

Current literature explores the key features of trading networks and how they relate to the price dynamics of cryptocurrencies. Liang, Li, and Zeng (2018) show that both Bitcoin and Ethereum trading networks display fluctuations in growth rates. For example, the clustering coefficient[1] of Bitcoin is initially 0.15, qualified as a small-world network[2], and decreases to around 0.05 later (Baumann et al. 2014; Kondor et al. 2014); in contrast, the clustering coefficient of Ethereum lies between 0.15 and 0.2 overtime and never identified as a small-word (Ferretti and D'Angelo 2019). Motamed and Bahrak (2019) built both monthly and accumulative networks of Ethereum. They found that the number of components[3] is around ten and increases over time; however, similar to the Bitcoin trading network, the graph density[4] of Ethereum decreases over time (Vallarano, Tessone, and Squartini 2020). Liang, Li, and Zeng (2018) also find the largest components of Bitcoin and Ethereum have large sizes in both diameters (around 100 for Bitcoin and gradually increase for Ethereum) and percentages (40~60%). The network structures differ significantly across blockchains. For instance, Chang and Svetinovic (2016) find that the Bitcoin network grows denser over time, where more nodes tend to be connected with each other, leading to a strong community while Namecoin resembles decreasing in density, ending up with an unclear community structure. Polovnikov, Kazakov, and Syntulsky (2020) demonstrate a core-peripheral structure (Gallagher, Young, and Welles 2021) in the cryptocurrency exchange networks.

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[1] Cluster coefficient describes the extent to which a network is aggregated together (Baumann et al. 2014).
[2] A small-world network refers to network in which most nodes are not neighbors of each other, but most nodes can be reached from other nodes by a small number of steps (Baumann et al. 2014).
[3] Components are pats of the network that are disconnected from each other (Vallarano, Tessone, and Squartini 2020).
[4] Network density describes the portion of the potential connections in a network that are actual connections (Vallarano, Tessone, and Squartini 2020).

A variety of algorithms have been developed for extracting the core-periphery structure by scholars (Malliaros et al. 2019), which differs typologically from their definitions of the nature of the network and how core and peripheral nodes are connected. We have the most popular Borgatti-Everett (BE) algorithm, which partitions the network into a central hub with interlacing nodes and a periphery radiating outward from the hub (Borgatti and Everett 2000). Cucuringu et al. (2016) also detect the core-periphery structure through spectral methods and geodesic paths based on the transportation networks. Besides the classical two-block methods, there also exist algorithms that build a continuous spectrum between a core and a periphery which could be applied in examples of collaboration, voting, transportation, etc. (Boyd et al. 2010; Rombach et al. 2017; Rossa, Dercole, and Piccardi 2013). The continuous structure enables the exploration of network components and features that are not apparently categorized either as core or periphery (Rombach et al., 2017). Considering that there may be more than a pair of core-periphery in the network, Kojaku and Masuda (2017 & 2018a) propose scalable algorithms to detect multiple groups of core and periphery in a network and demonstrate their application in the networks of political blogs and airports.

Our research extends the network studies on Bitcoin and Ethereum to the most up-to-date context of Ethereum 2.0 PoS, of which there exists only few study. Based on the existing literature, we will provide a more comprehensive network analysis methodology and network feature metrics of Ethereum. Moreover, besides testing the significance of core-periphery structure, we will deep in to the investigation of the functions and behaviors of cores, and how do they affect the network dynamics and level of decentralization.

2. Agent-based modeling

Hunseler and Lemke-Rust (2021) present a simulator for the Ethereum 2.0 Beacon Chain Network to verify hypotheses and attack scenarios without the need to actually stake cryptocurrency and fulfilling validator's obligations inside the network. They find that the results of conducted simulations show great correspondence to the behavior of the live Beacon Chain, and further implement various kinds of misbehavior to verify that misbehaving validators are slashed and deprived of their invested capital. However, this study failed to consider the the network structure and effects of incentive design on validators. Understanding the mechanisms of network formation is central in social network analysis. Yuan, Alabdulkareem, and Pentland (2018) propose a social network formation model that integrates methods in multiple disciplines and retain both heterogeneity and interpretability. They represent each agent by an "endowment vector" that encapsulates their features and use game-theoretical methods to model the utility of link formation.

Compared with existing studies, our proposed agent-based model is more close to the economic issue and mechanism design, with a brand-new application scenario, Ethereum 2.0 PoS. This muti-agent model will be able to demonstrated the network formation and the level of decentralization on Ethereum. Furthermore, we will verify our model with real data on the Beacon Chain.

3. Game theory in a distributed system

Game theory has been employed traditionally as a modeling tool for describing and influencing behavior in societal systems, which has recently emerged as a valuable tool for controlling or prescribing behavior in distributed engineered systems (Marden and Shamma 2015). Jaggard et al. (2017) use ideas from distributed computing and game theory to study dynamic and decentralized environments in which computational nodes, or decision makers, interact strategically and with limited information, the proposed model of which could be applied to social network analysis.

Distributed system is a system consisting of groups of servers and clients where they are connected together to do specific tasks (Mulyadi and Akkarajitsakul 2019). Luther and Stein Smith (2020) identifies Bitcoin as a distributed payment mechanism, which, process a transaction on a shared ledger based on the user network, is different to a decentralized one. Understanding how to incorporate this into the models used to design cryptocurrencies has motivated a large body of work, yet many open problems still exist and current systems rarely deal with incentive related problems well. This issue arises due to the gap between Cryptography and Distributed Systems security, which deals with traditional security problems that ignore the explicit consideration of incentives, and Game Theory, which deals best with situations involving incentives (Azouvi and Hicks 2020).

Our project contributes to the current study on network game theory by broadening and adapting its application to blockchain distributed systems, specifically the most recent Ethereum 2.0 Beacon Chain Network. Since most existing study focuses on the technical support of decentralization in a computational system, our additional of the game theory to the incentive design will achieve a breakthrough. We will complete the adjustment and optimization required by the application of this theory in distributed systems, and paved the way for subsequent scholars studying the application of Network Game Theory in distributed systems. Moreover, we extend the network game theory to study incentive design, which can show the effect of incentive design on the realization of network decentralization.

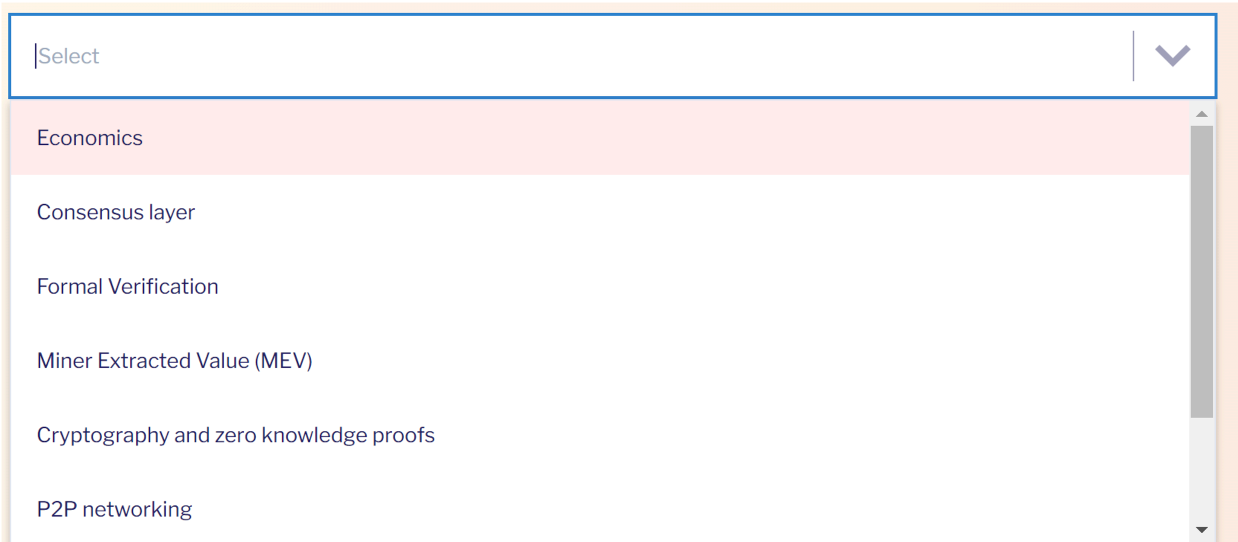
Practical Impacts

Our study would greatly contribute to reproducing and evaluating the current incentive design in Ethereum 2.0 Proof-of-Stake through game theory and proposed agent-based model simulation. Further, based on our analysis and assessment, we could motivate the improvement of the Ethereum 2.0 consensus incentive design by providing corresponding enhancement proposals with evidence.

References

Project category

Please choose a category that your project best fits in.



Team/Individuals description - A brief summary of your team's relevant experience*

Who is working on this project? Give us a bit of info and include relevant links, if available! Please provide other projects or research papers (ideally public and/or open source), engagements or other types of proof that your team has the necessary experience to undertake the project you are applying for.

Principal Investigators.

Prof. Gergely Horvath

Gergely Horvath, Ph.D., is an Assistant Professor of Economics at the Duke Kunshan University since July 2020. He received a Ph.D in Economics from the University of Alicante (Spain) in 2011. Later, He was a postdoctoral fellow at the Friedrich-Alexander University of Erlangen-Nuremberg in Germany and held faculty positions in China at the Southwestern University of Finance and Economics and the Xi'an Jiaotong-Liverpool University. His research focuses on behavioral and experimental economics, social network analysis and labor economics. His articles appeared in various academic journals, including the European Economic Review, Journal of Economic Behavior and Organization, Scandinavian Journal of Economics, Journal of Public Economic Theory, PLoS One, Journal of Behavioral and Experimental Economics, Economics Letters and Journal of Theoretical Biology, among others. More information on his current research can be found on my webpage: https://sites.google.com/site/horvathgergely/

Prof. Luyao Zhang:

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Luyao Zhang (Sunshine) is Assistant Professor of Economics and Senior Research Scientist at the Data Science Research Center at Duke Kunshan University (DKU). She has an abiding passion for interdisciplinary collaborations, especially for those related to computational economics (algorithmic game theory and mechanism design), crypto-economics (blockchain for social good, DeFi, and consensus algorithms), artificial intelligence (machine learning, AI trust, Human-Computer Interactions), and interdisciplinary big data (social media, sustainability, and global health). Her publications appear in economic journals for general interest and beyond, including American Economic Review: Papers and Proceedings, the Review of Economics and Statistics, the World Economy, Nature Scientific Data, ACM CCS, Remote Sensing, Journal of Digital Earth, Data and Information Management, etc. She has served the academic community and beyond. She serves on the research policy committee, the advisory board of the mind group as social science division representative and on the faculty advisor program for student care at Duke Kunshan University. She also is the associate editor for IEEE Transactions on Computational Social System and the ambassador in Shanghai for Startup Genome. She is the Founding President for SciEcon CIC, NPO registered in the UK, aiming to cultivate integrated talents in research, innovation, and leadership. She was the Founding President of Dance Illumination, an NPO with 501 (c)(3) tax-exempt status to promote diverse dance histories. She received Ph.D. in Economics at Ohio State University, supported by Presidential Fellowship and NSF dissertation grant. She graduated from Peking University with a B.A. in Economics and a B.S. in Math and Applied Math. She holds a blockchain strategy certificate from Oxford University and more than 30 certificates in Data Science.

Student Research Fellow:

Ziqiao Ao:

Ziqiao Ao is a senior student at Duke Kunshan University, majoring in Data Science. She was well trained in the area of data science and business intelligence. Through previous experience, she made practical use of programming and data analytic tools, cultivating unique insights in blockchain, Decentralized Finance (DeFi), cryptocurrency and Social Network Analysis (SNA). Also, she participated in multiple data-analytics projects, which strengthened her skills in data crawling, modeling, optimization and machine learning. Additionally, she has made a mediocre achievement in employing rigorous technological methods to address problems in economics, finance, internet, e-commerce, etc., and have unfurled myself to these industries.

Relevant past publications*

Any links for us to review? E.g. research papers, blog posts, etc.

Grant Scope*

What are you going to research? What is the expected output?

1. We focus on studying the current Ethereum Network Formation by providing i) empirical studies, ii) game theory, and iii) agent-based model simulations based on the existing literature to study the effect of incentive design on the realization of decentralization on Ethereum.
2. We might conduct some pilot research for Ethereum 2.0 Beacon Chain (Beaconcha.in, n.d.). If the upgrades to Ether 2.0 do not complete, we can start with evaluate Ethereum 1.0, but we will leave the comprehensive studies of Ethereum 2.0 for a continue projects.

With a clear basis and context, our methodology should be generally applicable and easily adapted to Ethereum 2.0 scenarios, and the model will be promising and easy to achieve. For the model evaluation, we will acquire public-available data set from the Beacon Chain (Beaconscan, n.d.), which is a small scope given its recency.

The expected output of this study includes

- Blog post (medium article for exploratory research)
- Datasets published on Harvard Dataverse
- Code published on Github
- Working paper published on arxiv
- Working paper submitted to conference
- Host Academic events such as seminar and symposium
- Present at international conferences

Project goals & success factors*

What are you hoping to accomplish with this grant? How do you define and measure success for this project?

For our first research question (i.e. How do incentives in Ethereum 2.0 Proof-of-Stake affect agents' behavior and network formations?), we will firstly build theoretical model with game theory to simulate the network formation and study the incentive design of the Ethereum PoS. Lastly, we will build muti-agent model to simulate the network formation and agents behavior.

For the second research question (i.e. How does changing the incentive design in Proof-of-Stake affect the realization of network decentralization?), we plan to firstly conduct empirical study of network analysis to investigate the network dynamic and extract features representing level of decentralization and network formation. Then, we will incoporates network features to our game theory model (combined with network) to study how the change of incentive design will affect the level of decentralization.

Below we will further explain the rationale of our study:

Ethereum 2.0

Ethereum 2.0 is an upgrade to the Ethereum blockchain. The upgrade aims to enhance the speed, efficiency, and scalability of the Ethereum network so that it can process more transactions and ease bottlenecks (Millman 2020). The first upgrade of Ethereum 2.0 is launching the Beacon Chain, which introduces native staking to the Ethereum blockchain, a key feature of the network's shift from a proof-of-work (PoW) consensus to a proof-of-stake (PoS) consensus mechanism (Ethereum 2022). PoW algorithms adjust their difficulty based on the total hashpower securing the network, the first miner to solve a puzzle adds a new transaction to the record of all transactions that make up the blockchain. So the problem always takes roughly the same amount of time to solve, which costs much energy (Ross 2022). PoS differs from PoW in that instead of miners, users can stake a network's native cryptocurrency and become validators, who are similar to miners in that they verify transactions and ensure the network isn't processing fraudulent transactions. These validators are selected to propose a block based on how much crypto they have staked, and how long they've staked it for. When there are enough attestations, a block can be added to the blockchain. Validators are then rewarded for the successful block proposition. The main advantage of PoS is that it is far more energy-efficient than PoW, as it decouples energy-intensive computer processing from the consensus algorithm. With a large distributed network of validators, it also comes with an inherent decrease in security (Ethereum 2022; Millman 2020; Ross 2022).

Social Network Analysis

Our study will conduct a comprehensive analysis of the Ethereum transaction network by extracting network features including the numbers of nodes and edges, the mean and standard deviation of degree., top 10 degrees mean ratio, relative degree, modularity, the count of components, the count of core, and giant component ratio, etc.

A commonly adopted notion in social network analysis is the core-periphery structure, which presents two qualitatively distinct components: "core" nodes that are densely connected, and "periphery" nodes that are loosely connected only to the core members but not necessarily among each other (Gallagher, Young, and Welles 2021). Core-periphery structure enables us to compare and analyze the properties of the two types of nodes more accurately and efficiently under different contexts structurally and functionally (Csermely et al., 2013).

Its capability also enables it to be widely applied in the financial field along with SNA. Sui, Tanna, and Zhou (2019) constructed a core-periphery interbank network that distinguishes the financial banks by balance sheet size and connections to investigate the financial contagion. In the cryptocurrency market, the core-periphery structure of the stable assets based on liquidity and capital inferred by a network feature is examined to study the market impact and evolution (Polovnikov, Kazakov, and Syntulsky 2020).

Given diverse core-periphery structures defined by algorithms, we would apply the Borgatti-Everett (BE) algorithm (Borgatti and Everett 2000) to the transfer network while examining Kojaku and Masuda's (2018a) algorithm of multiple pairs along with SNA to test the level of decentralization, we will also specifically investigate in cores that influences the network (i.e. centralized exchanges/smart contracts of major functions).

Theoretical modelling of Ethereum.

Game theory has been employed traditionally as a modeling tool for describing and influencing behavior in societal systems, which has recently emerged as a valuable tool for controlling or prescribing behavior in distributed engineered systems (Marden and Shamma 2015). Jaggard et al. (2017) use ideas from distributed computing and game theory to study dynamic and decentralized environments in which computational nodes, or decision makers, interact strategically and with limited information, the proposed model of which could be applied to social network analysis. Christakis et al. (2020) develop and analyze a tractable empirical model for strategic network formation that can be estimated with data from a single network at a single point in time. Besides, Yuan, Alabdulkareem, and Pentland (2018) propose a social network formation model that integrates methods in multiple disciplines and retain both heterogeneity and interpretability. They represent each agent by an "endowment vector" that encapsulates their features and use game-theoretical methods to model the utility of link formation.

There will be 3 types of agents in our model: i) miners, ii) validators, and iii) traders. We will assume the agents to be rational, who minimize their costs and maximize profits during trade, and will consider mutiple actions in the network, including transaction, staking, attack, etc. The incentive design will be initially set based on the incentive design of Ethereum 2.0, and will be adjusted and optimized according to our preliminary results.

Agent-based simulation

An agent-based model (ABM) is a computational model that can simulate the actions and interactions of individuals and organizations in complex and realistic ways, which could provide precious information and insights about the complex dynamics and characteristics of the real-world system. Agent-based models are not constrained by many of the constraints and empirical problem assumptions of most mainstream economic models (Iori and Porter 2012).

Hunseler and Lemke-Rust (2021) present a simulator for the Ethereum 2.0 Beacon Chain Network to verify hypotheses and attack scenarios without the need to actually stake cryptocurrency and fulfilling validator's obligations inside the network. They find that the results of conducted simulations show great correspondence to the behavior of the live Beacon Chain, and further implement various kinds of misbehavior to verify that misbehaving validators are slashed and deprived of their invested capital.

The decision environment of our proposed agent-based model will be trading in Ethereum 2.0 Beacon Chain Network. We will assume the agents to be rational, who minimize their costs during trade. Besides, considering the bounded rationality, we will repeat simulations with the same initial conditions but different seeds of the random number generator and parameter setting and use real data to conduct a comparative study and select the optimal simulation.

Real data acquisition

For the empirical analysis and model evaluation, we will acquire public-available data set from the Beacon Chain (Beaconscan, n.d.), which is a small scope given its recency, and we will be able to get access to the data due to the publicity characteristic of Ethereum.

What problem are you trying to solve?*

Ethereum is designed as a distributed system technique but the realization of network driven by incentive design is not up to the promise of decentralization. The Ethereum protocol focuses on providing a platform to facilitate building decentralized applications on its blockchain, it adopts a chain selection rule to harness the residual mining power in pruned blocks for improved security. Gencer et al. (2018) investigate the extent of decentralization by measuring the network resources of nodes and the interconnection among them, the protocol requirements affecting the operation of nodes, and the robustness of the two systems against attacks. They discovered that Ethereum does not have strictly better decentralization properties than the other. There exits no apparent rationale or evidence for us to believe the realization of decentralization on Ethereum, which is the problem we will try to solve in our study.

How does this project benefit the greater Ethereum ecosystem?*

Our project will demonstrate the significance of the realization of decentralization on blockchain, especially Ethereum 2.0. Further, through investigating the effect of Ethereum 2.0 PoS incentive design on decentralization, our proposed theoretical and agent-based models can provide concrete incentive design advice o Ethereum 2.0 upgrades to help enhance the realization of decentralization.

Total budget requested*

Estimated grant amount. Ex: USD 50,000.

Stipend for faculties:

10,000~1,5000 USD stipend for a month working hour per month

(2 PIs * 2 months)

Student Project manager and team leaders (Ziqiao)

Internship: Ziqiao
(75RMB) 12~15 USD per hour

160 h per month *3 month

40h per month * 3 month

Another 6 student workers/internship from Duke

40h*3 per month * 3 month
VM

Indirect cost at DKU

Budget breakdown and project roadmap*

Please include a brief explanation on the milestones/roadmap in a 3-6 months timeframe, along with expected deliverables. Also outline how the funds will be used for the research project and/or members of the team.

Budget breakdown:

1. Academic supply
    a. Virtual Machine setup (first month, strengthen the computaional power)
    b. Overleaf subscription (for manuscript construction)
2. Research fellow depend (salary of the research fellow in our team)
3. Expert consulting fee

Roadmap:

Phase 1 (June to Aug.)

June: Literatre review, network analysis, core-pherphery analysis

July: Game theory and agent-based model construction

Aug: Agent-based model simulation and analysis

Phase 2: (Sep. to Nov.)

Sep: Model evaluation and verification with real data

Oct: Datasets and code published, complete the final paper draft

Nov: Complete final paper

Challenges*

Have you come across any obstacles thus far? If so, how have you attempted to tackle these issues? Have you been successful in overcoming them?

Due to the data and computation complexity of network feature extraction, we faced some computational issues, we later solved this issues by implementing the algorithm in the VM.

Interdisciplinary:
1. data science
2. network studies
3. behavioral science
4. blockchain
5. game theory.

learning from each other and completed a pilot research, give the paper title and URL to view PDF.

Additional support requests

Aside from funding and financial support, are there other resources that would help you or your team succeed?

The additional resources listed below would be extremely helpful for our study:

1. Invitations to Ethereum Foundation Sponsorship conference for communicating to the result to broader the understanding of Ethereum economy.
2. Potentially provide more technique support for Ethereum Data. (We can query the data on our own. But if some engineers already have the data, it would be environmentally friendly to share the data for academic research.)