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Unraveling the crypto market: A journey into decentralized finance transaction network

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ABSTRACT

The explosive growth of decentralized finance (DeFi) has revolutionized the accessibility and functionality of financial services. To gain valuable insights into this evolving ecosystem, analyzing transaction data using network analysis methodology proves to be highly effective. Network analysis allows us to uncover intricate relationships, patterns, and communities within the DeFi market by examining participant transactions. We model nodes group representing actors or wallet addresses, and edges represent transactions between wallet addresses. This study focuses on three prominent DeFi token-based Ethereum protocols: DAI, UNI, and WBTC. We analyzed 5,802,742 transaction data spanning from January 2022 to January 2023 of those three tokens. Using network topology metrics, we uncover market size, average transaction of each wallet address, market density, and reachability (diameter). We also detect the presence of transaction clusters and grouping quality using the modularity metric. At last, we employ centrality calculation to identify the most important wallet address and their role in the market. We gain insight by comparing those three tokens and reveal valuable insight into patterns and relationships, network dynamics, decentralized nature, and the presence of intermediaries in the token economy market. Our objective is to uncover hidden dynamics and trace asset flows, which can provide valuable information to market participants, regulators, and innovators seeking to optimize the DeFi infrastructure, ensure stability, and mitigate risks. Leveraging the power of network analysis offers the potential to shape the future of DeFi by enhancing efficiency, security, and accessibility, thereby fostering financial inclusion and empowering individuals and businesses globally.

1. Introduction

Globalization actively changes societies and economic activities, expanding transactions and enabling their execution anywhere and anytime (Dasgupta & Grover, 2019). Most financial transactions still use traditional systems that require third parties, such as banks, as intermediaries between the sender and receiver, which has many drawbacks. The 2008 financial crisis is one example of the poor traditional financial system. Many factors that trigger the crisis are the lack of transparency in financial management and the negligence of some parties that harm economic stability through careless lending, financial manipulation, and collusion with regulators (Schenk, 2021). Other limitations of international payment methods include the need for payment intermediaries, high transfer fees, relatively long transaction time, and payment inefficiencies (Wu & Duan, 2019).

The fast-paced progress of technology dramatically influences the disruption in the financial sector. Nowadays, people have high

expectations from the financial services industry, demanding secure, efficient, and expeditious fund transfers (Bank Indonesia, 2020). The rise of interaction platforms and ecosystems, such as social networks, e-commerce, and media-sharing services, intensify social interaction, collaboration, and transaction. Massive social interaction from large-scale social networks potentially led to substantial economic activities (Eagle, Macy, & Claxton, 2010). Thus, digital transactions and asset exchange must be a native part of the ecosystem to support seamless transaction experiences. Information and communications technology advancements have greatly impacted the financial domain as we move toward a super-connected society. Technology integration into the financial sector has led to the emergence of innovative solutions known as FinTech, which revolutionize various aspects of financial services. These FinTech solutions are reshaping how financial transactions are conducted, providing users convenience, speed, and efficiency. One way to achieve financial activities embedded in society is through peer-to-peer transaction and exchange capabilities.

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Decentralized Finance (DeFi) is an emergent financial technology based on secure distributed ledgers similar to those used by cryptocurrencies. It removes the control banks and institutions have on money, financial products, and financial services. Its key features include decentralization, transparency, and the ability for users to participate in complex blockchain transactions using smart contracts freely. It is a revolutionary innovation in the financial sector, facilitating peer-to-peer financial activities on entirely digital platforms. This groundbreaking approach has garnered significant attention for its transformative impact on the digital economy (Damalas & Stafford, 2021). It offers a multitude of advantages, such as enhanced security, improved transparency, and cost-effectiveness (Farrington, 2021) compared to traditional financial (TradFi) systems. Central to DeFi's robustness is its reliance on Blockchain technology, which guarantees the security and integrity of transactions. Yu, Liu, Zhang, and Guo (2022) highlight the technology's immutability, emphasizing its reliability due to its resistance to alterations. Key components of this technology include Smart Contracts and Distributed Ledger Technology (DLT). Smart Contracts necessitate comprehensive assessments by the involved parties, ensuring mutual agreement before execution. On the other hand, DLT enhances transaction security by distributing records across multiple nodes, and employing consensus algorithms for data validation, ensuring real-time data accuracy across all nodes (Alamsyah & Syahrir, 2023). Table 1 offers an in-depth comparison of Traditional Finance (TradFi) and Decentralized Finance (DeFi), shedding light on the contrasting features of these two financial systems (Naggar, 2023). We compare several important aspects of how DeFi offers various advantages over TradFi in terms of centrality, transaction costs, transparency, security, regulation, asset control, and accessibility (Qin, Zhou, Afonin, Lazzaretti, & Gervais, 2021; Wharton Blockchain and Digital Asset Project & World Economic Forum, 2021).

To enhance the security of transactions without intermediaries, DeFi leverages blockchain technology, utilizing private keys to authenticate transactions and deter fraudulent activities. As highlighted by Tasca and Tessone (2018), this system relies on cryptographic methods to validate transaction integrity, ensuring that only legitimate transfers are processed. DeFi's infrastructure inherently removes the need for traditional intermediaries, like banks, to facilitate direct exchanges between transacting parties (Wu & Duan, 2019). This shift streamlines

transactions and grants all participants access to a transparent ledger of all transaction histories, as Alamsyah, Hakim, and Hendayani (2022) noted. Furthermore, platforms like Etherscan.io play a pivotal role in maintaining transparency within the DeFi ecosystem. Etherscan.io allows for easy tracking and analysis of past transactions on the Ethereum blockchain, offering comprehensive data that can be used for scrutinizing token exchanges (Chen, Xia, Lo, & Grundy, 2022). This visibility into the transaction network among addresses provides insights into the trading patterns associated with tokens, contributing to the overall security and reliability of the DeFi system.

The rapid growth of DeFi comes as no surprise, considering its advantages. Reaching an approximate Total Value Lock (TVL) of USD 77.29 billion in June 2022, the growth of DeFi advances at a rapid pace. The TVL increased compared to the same month in 2020, only reaching USD 1.91 billion (Statista, 2022a). In 2020, there were 1000 new assets in the DeFi ecosystem; in July 2022, more than 4.8 million accounts conducted transactions (Statista, 2022b). Besides the increasing TVL, the market capitalization of DeFi in June 2022 reached USD 61.2 billion, a significant increase from June 2020, which was only around USD 5.8 billion (Coingecko, 2022). This ascending trajectory underscores the evolving dynamics of the crypto market, with the DeFi transaction network poised to offer nuanced insights into these transformations. Following those facts, our motivation is driven by the interest in the resilience and vulnerabilities of the DeFi market. The research question focuses on understanding the dynamics of the DeFi market and getting insight from the transaction pattern. We will employ a network science approach to measure network dynamics using several well-known metrics and aspects such as local connection, global pattern, grouping, robustness, and flexibility.

Network science, a multifaceted discipline focused on exploring network dynamics and topologies, plays a pivotal role in unraveling the complexities of transaction networks within the DeFi ecosystem (Barabási, 2016; Newman, 2010). Utilizing network-based methodologies enables a profound exploration and comprehension of intricate transactional patterns and processes across a multitude of domains (Guo, Dong, & Wang, 2019). In the realm of DeFi, network science facilitates a structured representation of transaction networks, where wallets are conceptualized as nodes, and the flow of funds between these wallets is illustrated as edges (Fleder, Kester, & Pillai, 2014; Nadini, Alessandretti, Di Giacinto, et al., 2021). This strategic representation has gained substantial traction for its efficacy in extracting valuable insights from transactional data within the financial sector (Alamsyah, Ramadhani, Kristanti, & Khairunnisa, 2022). Employing network science in this context provides a comprehensive lens to discern and analyze the interconnectivity and transaction patterns among various entities within the network. Through meticulous network analysis, it becomes feasible to garner a deeper understanding of the overarching transactional landscape and the nuanced interrelations within the DeFi ecosystem.

Research in the crypto industry has been flourishing, but a conspicuous gap persists in the DeFi network transaction analysis area. A majority of existing studies have predominantly zeroed in on popular cryptocurrencies like Bitcoin and emergent trends such as Non-Fungible Tokens (NFTs) (Motamed & Bahrak, 2019). Liang, Li, and Zeng (2018) conducted a comparative analysis, scrutinizing transaction graphs and tracing the dynamics of cryptocurrencies such as Bitcoin, Ethereum, and Namecoin. In another nuanced study, Motamed and Bahrak (2019) delved into a comparative exploration, evaluating cryptocurrencies like Ethereum, Litecoin, Dash, and Z-Cash. Their inquiry, however, was circumscribed primarily to network transaction graph properties, such as nodes, edges, and density. Chen, Zhang, Chen, Zheng, and Lu (2020) conducted an extensive analysis focusing solely on the Ethereum token ecosystem, characterizing diverse activities related to token creation, ownership, and transfer. Nadini et al. (2021) oriented their research toward the NFT market, examining its statistical properties and formulating a trader interaction network. It emerges that a focused exploration into DeFi network transaction analysis remains limited, with a few

Table 1
TradFi vs. DeFi Comparison.

Aspect	TradFi	DeFi
Centrality	Centralized, managed by an institutional entity or financial organization	Decentralized, it is governed and regulated by users or developer communities
Transaction fees	Entails higher transaction fees due to the involvement of third-party intermediaries	Tend to be lower as they do not involve intermediaries
Transparency	Transactions are not publicly accessible	open access to transaction flows, market prices, and asset ownership
Security	Attacks can frequently target centralized systems, posing a potential risk of widespread disruption to the entire system	uses blockchain and smart contracts for a more decentralized security approach, reducing vulnerability to hacking and cyber-attacks.
Regulation	The financial regulator enforces regulations and rules.	No regulators, more freedom and flexibility in innovation
Asset control	Managed by companies or financial institutions, such as banks or stockbrokers.	Users have complete control over their crypto assets
Accessibility	limited to those who possess access to traditional financial infrastructure, such as banks, stock markets, and other financial institutions	Open to anyone with internet access and a crypto wallet, provides global access without geographical or financial limitations for financial products and services

research focusing on this area, one of them being AAVE DeFi token transaction network (Ao, Horvarth, & Zhang, 2023), which is limited on core-periphery structure identification; thus more granular analysis is needed. It highlights an opportunity for further research to navigate the intricacies of DeFi transactions, bridging the existing gap in the current body of knowledge.

We embark on an empirical analysis dedicated to unraveling the mechanisms of DeFi tokens within the crypto industry, with a special emphasis on the Ethereum platform. As per the data of November 2022, Ethereum commands a predominant position in the sector, boasting a market capitalization that encapsulates 58.1% of the Total Value Locked (TVL) in DeFi across various blockchain tokens (Dehmer & Basak, 2012). Our analytical lens specifically zooms in on Ethereum-based DeFi tokens such as Dai (DAI), Uniswap (UNI), and Wrapped Bitcoin (WBTC). Noteworthy is that these tokens utilize Ethereum as their foundational platform and prominently feature as the top three tokens by market capitalization as of January 2023, according to [Coinmarketcap.com](https://www.coinmarketcap.com) (Coinmarketcap, 2023). This research aims to uncover hidden dynamics, detect influential actors, and trace the flow of assets, which could inform market participants, regulators, and innovators on ways to optimize the DeFi infrastructure, ensure stability, and mitigate risks. The academic contributions of research on DeFi transaction networks, especially in financial innovation, provide insights into new financial systems, economic and game-theoretical aspects, regulatory and legal implications and foster cross-disciplinary collaboration among experts in computer science, economics, finance, cryptography, and law (Friesendorf & Blütener, 2023; Schär, 2021). Another aspect to consider as the motivation is the availability of open transaction data of the DeFi ecosystem, which benefits us. Here, we analyze over 5 million transactions for January 2022 to January 2023 containing those three tokens.

The paper organization has been constructed as follows. Section 1 serves as the introduction and establishes the context by providing the research background, motivation, objectives, significance, and relevance of the research. Moving forward, section 2 compiles and presents pertinent studies, works, and theories closely aligned with the research topic. Section 3 outlines the comprehensive research plan and framework employed in the study. It details the approach taken for data collection, research design, and the analytical techniques used, ensuring transparency and replicability. Section 4 presents the research findings by offering explanations and insights into their implications. The study's potential impact is discussed, shedding light on its relevance and contribution to the field of DeFi and the crypto market in general. Lastly, section 5 presents the conclusion to facilitate readers' understanding of the research's key findings. It encapsulates the primary outcomes and their potential impact in the realm of DeFi, leaving readers with a clear understanding of the research's value and potential for further exploration.

2. Literature review

2.1. Blockchain and Ethereum

Blockchain technology represents the latest innovation in storing encrypted data through decentralized "blocks" that are interconnected in a "chain" (Levis, Fontana, & Ughetto, 2021). This technology offers a range of advantages, including decentralization, transparency, security, strong privacy, and data immutability (Tasca & Tessone, 2018). Despite its promising potential, the full extent of blockchain's capabilities in different domains remains largely unexplored. Researchers are intensifying their efforts and expanding the scope of their investigations to uncover additional opportunities blockchain presents and overcome the issues. Numerous studies recognize blockchain's myriad benefits and diverse applications in finance (Alamsyah & Syahrir, 2023; Javaid, Haleem, Singh, Suman, & Khan, 2022), supply chain management (Chang, El-Rayes, & Shi, 2022), and real estate (Ali Syed et al., 2019).

Blockchain technology enhances various sectors by ensuring data

security and improving operational efficiency and transparency. In the financial industry, it revolutionizes banking transactions, reducing costs and improving competitiveness through collaborations like the R3 blockchain consortium, and modernizes securities and stock exchanges by streamlining processes, reducing risks and costs (Mainelli & Milne, 2016; Tapscott & Tapscott, 2017; Y. Guo & Liang, 2016; Ervin, 2018; Nasdaq, 2017). Ethereum, a prominent blockchain platform, leads in supporting diverse smart contracts and tokens, enhancing the execution and management of transactions and contracts in the digital space (Chen et al., 2020; Schär, 2021).

Blockchain technology acts as the architectural backbone of the DeFi industry, embodying a spectrum of functionalities pivotal for its advancement. It fosters decentralization, allowing a peer-to-peer financial ecosystem free from traditional central authorities like banks. Blockchain hosts smart contracts, facilitating automated, secure transactions and various DeFi services such as lending, borrowing, and trading. Moreover, blockchain facilitates decentralized governance, liquidity and yield farming mechanisms, and cross-chain services, further enriching the DeFi industry's operational landscape. These functionalities collectively position blockchain as a transformative force, driving innovation, security, and user empowerment in the DeFi industry (Alamsyah & Syahrir, 2023).

Blockchain boosts transparency and security in other applications, such as supply chain and healthcare. It allows for accurate traceability of products and assets, ensuring authenticity and compliance and enhancing consumer trust across industries like food and pharmaceuticals (Alamsyah, Hakim, & Hendayani, 2022; Deloitte, 2017; Haleem, Javaid, Singh, Suman, & Rab, 2021; Krawiec, Housman, & White, 2018; Kuo & Ohno-Machado, 2018; Peterson, Deeduvanu, Kanjamala, & Mayo, 2016; Xu, Guo, Xie, & Yan, 2020). In asset and real estate management, blockchain facilitates secure and efficient property transactions, preventing fraud and enhancing tax collection processes (Karamitsos, Papadaki, Barghuthi, & Al., 2018; Spielman, 2016; Veuger, 2018).

2.2. Token and tokenization

Tokens are digital representations of assets within a blockchain that are recorded as entries in a blockchain address's ledger (Schär, 2021). These entries contain the rules set by smart contracts, which can only be accessed by wallets possessing the private key associated with the respective address (Voshmgir, 2020:33–34). Standardized token creation processes have been adopted to simplify the trading and transfer of tokens across various platforms and mitigate compatibility concerns. One widely utilized standard is ERC-20, which holds significant popularity within the Ethereum network. Asset tokenization involves the creation of digital tokens that represent real-world assets (RWA) and are recorded on a blockchain. Tokenizing assets like land, art, and digital assets can lead to cost reductions for issuers, improved transparency, efficiency, and liquidity for real-world assets, as well as opening new possibilities for reimagining the economy. Tokenized assets offer several advantages over traditional assets, including enhanced speed, adaptability, security, and practicality. By tokenizing traditionally illiquid assets, their liquidity can be increased, unlocking potential value for investors. Similar advantages could be achieved when implemented in the financial sector, leading to innovative solutions, and providing secure asset representation between financial institutions and traders, potentially eliminating the need for traditional clearing processes, and significantly reducing settlement times (Frick, 2021).

The rise of DeFi and asset tokenization heralds transformative advancements in the financial sector, unveiling a spectrum of opportunities across various market segments, including Equity & Real Asset Markets, Fixed Income Markets, and Credit Markets. Real-World Assets (RWAs) emerge as pivotal instruments within DeFi, extending their influence across diverse financial products and platforms such as Backed Finance and Synthetix, which offer an array of equity and derivative

products, including crypto asset derivatives (Frick, 2021). The profound impact of RWAs in democratizing access to previously exclusive private credit markets is noteworthy, thus broadening investment opportunities. Platforms like Ondo Finance and BondBlox exemplify this, offering diverse RWA funds and selections, and marking historic milestones with substantial cumulative values in private credit loans. Central to the DeFi ecosystem are stablecoins, which sustain a pivotal role by ensuring price stability and facilitating seamless entry into DeFi, thus enhancing the operational fluidity and inclusivity of the crypto markets (Naggar, 2023). RWA tokenization stands as a fundamental pillar of DeFi, holding the potential to inject liquidity into markets, contingent upon the presence of suitable infrastructure for asset exchange. DeFi's overarching objective is to supplant existing financial services with decentralized alternatives, ushering in a more efficient and secure financial system. The advantages of RWA in DeFi are multifaceted, with the capability to reshape our perception of finance, democratize access, and enable previously unattainable business models. As DeFi continues to expand and progress, it will reshape the current financial landscape, paving the way for a transformative future (Rejolut, 2023).

Tokenization is essential in the DeFi ecosystem as it allows for the representation and management of assets on a blockchain. This digital representation enables a seamless and efficient transfer of ownership and value. Furthermore, tokenization opens up new possibilities for creating novel applications and services within the blockchain ecosystem. Using blockchain technology, tokenization allows for transforming physical and nonphysical assets into digital tokens. These tokens can then be freely divisible and transferable, making them ideal for executing transactions and ownership transfers (Schletz, Cardoso, Prata Dias, & Salomo, 2020). There are several tokenization methods within the DeFi ecosystem, each serving a specific purpose. They are fractional ownership, wrapped tokens, NFT, and Minting and Burning.

- **Fractional Ownership:** This tokenization method involves dividing ownership of an asset into smaller, tradable units, allowing multiple investors to hold asset shares. For example, a real estate property could be tokenized into numerous fractions, enabling investors to buy and trade smaller portions of the property.
- **Wrapped Tokens:** This method involves representing an underlying asset on a blockchain. It serves as a bridge between the traditional financial system and the decentralized ecosystem. For example, a wrapped Bitcoin is a tokenized version of Bitcoin that can be used on Ethereum's blockchain.
- **NFT:** This method is used to tokenize unique assets representing ownership of a unique item, piece, or content. For example, a digital artwork or a rare collectible can be tokenized as an NFT, certifying its authenticity and ownership.
- **Minting and Burning:** This method involves creating (minting) and destroying (burning) tokens to regulate their supply. For example, a project may mint new tokens when there is a need to increase supply, and burn tokens when there is a need to decrease supply. These tokenization methods provide flexibility and functionality within the DeFi ecosystem, allowing for diverse use cases and investment opportunities.

The DeFi ecosystem has witnessed rapid growth in the number of introduced tokens. These tokens can be categorized into various categories based on their functionality and purpose within the DeFi ecosystem. Some common categories of DeFi tokens are shown as follows:

- **Stablecoins** are tokens designed to maintain a stable value, often pegged to a fiat currency like the US dollar. For example, Tether, USD Coin, and Binance USD are well-known stablecoins in the DeFi. They work by being backed by fiat currencies or other assets, providing stability and liquidity. They provide stability within the volatile

crypto market and are commonly used as a medium of exchange within the DeFi ecosystem.

- **Governance tokens** allow holders to participate in the decision-making process of a decentralized protocol or platform. For example, the Compound's COMP token grants holders voting rights on protocol upgrades and decisions. They allow token holders to propose and vote on changes to the protocol's governance parameters, such as interest rates or collateral factors.
- **Utility tokens** provide access to specific goods, services, or functionalities within a decentralized application (dApps) or platform. For example, the Uniswap token UNI is a utility token that grants users access to various features and benefits within the Uniswap protocol, such as fee discounts or voting power in governance decisions. They work by being used to access and utilize specific services or features within the DeFi platform.
- **Lending and borrowing tokens** are used for lending and borrowing activities within decentralized lending protocols. They enable users to lend their assets and earn interest or borrow assets by providing collateral. For example, Aave's LEND token is a lending and borrowing token that allows users to earn interest on their deposits and borrow assets against their collateral. They work by incentivizing users to participate in the lending and borrowing activities within the DeFi ecosystem.
- **Protocol tokens** represent ownership or stake in a decentralized protocol. These tokens typically grant holders certain rights, such as voting power or a share of the protocol's revenue. For example, the MakerDAO's MKR token is a protocol token that grants holders voting rights and a share of the revenue generated by the MakerDAO platform. They work by giving token holders ownership rights and a stake in the decentralized protocol, allowing them to participate in decision-making processes and potentially benefit from the protocol's success.
- **Yield farming tokens** are used in liquidity mining and yield optimization strategies within the DeFi ecosystem. They work by providing incentives and rewards for users who provide liquidity to decentralized exchanges or participate in yield-farming strategies. For example, Yearn.finance's YFI token is a yield-farming token that rewards users for providing liquidity to various DeFi protocols and optimizing their yield-generating strategies.
- **Synthetic tokens** are another category of DeFi tokens that replicate the value of other assets, such as traditional currencies or commodities, through smart contracts. They allow users to gain exposure to the price movements of these assets without actually owning them. For example, Synthetic tokens such as Synthetix's SNX token replicate the value of stock or commodities or external assets such as gold, US Dollar, or specific stock, allowing users to trade and gain exposure to their price.
- **Liquidity tokens** represent ownership or participation in liquidity pools within decentralized exchanges. Liquidity tokens enable users to provide liquidity to decentralized exchanges by depositing their assets into liquidity pools. They allow users to earn fees and rewards from the trading activity within the liquidity pool. For example, Uniswap's UNI token represents ownership or participation in liquidity pools on the Uniswap decentralized exchange.

3. Research methodology

3.1. Data and methodology

3.1.1. DAI, UNI, WBTC tokens

DAI, a stablecoin digital currency, is well-known for its ability to facilitate secure and reliable payments due to its minimal price fluctuations. Stablecoins like DAI play a crucial role in stabilizing the volatile cryptocurrency market by pegging their value to real-world assets such as fiat currencies or commodities like gold. This stability makes stablecoins an excellent choice for everyday transactions and enables faster

and more cost-effective cross-border transfers than traditional banking systems. DAI specifically maintains alignment with the USD, making it highly popular among users (Binance, 2020a; MakerDAO, 2017). As of December 2022, the market capitalization of DAI reached USD 5.75 billion. Among the notable decentralized finance applications that utilize DAI extensively is the MakerDAO platform, which allows users to generate DAI using their cryptocurrency holdings as collateral.

UNI serves as the primary governance token for Uniswap, a decentralized exchange platform built on the Ethereum blockchain. Users can trade Ethereum with other tokens created on the same blockchain through UNI. Uniswap facilitates direct peer-to-peer trading to improve transaction privacy and efficiency (Leech, 2021). The platform relies on liquidity pools to ensure ample liquidity availability. It offers incentives for liquidity providers through fee earnings while mitigating counterparty risk and increasing participant transparency and trust (Binance, 2020b). As of December 2022, Uniswap has emerged as the leading decentralized exchange platform with a market capitalization of approximately USD 3.91 billion (Coinmarketcap, 2022).

WBTC, an Ethereum-based token, represents the value of Bitcoin at a one-to-one ratio (Diyana, 2023). By utilizing WBTC within the DeFi ecosystem, users can expand its potential applications and enhance flexibility and interoperability between the two blockchains. Additionally, WBTC leverages liquidity to benefit DeFi (OKX, 2022; Tran, 2022; WBTC, 2023). As of December 2022, WBTC ranked fourth among the top DeFi tokens in market capitalization, with a total value of USD 3.03 billion (Coinmarketcap, 2022).

Our study focuses on these three tokens for several reasons. First, they are constructed on the Ethereum platform, which stands as the most widely utilized platform and fundamental infrastructure for DeFi applications. Second, DAI, UNI, and WBTC occupy the top three positions in market capitalization among tokens built on the Ethereum blockchain based on coinmarketcap.com as of January 2023. Third, these tokens represent key aspects of the DeFi ecosystem, covering stablecoins, decentralized exchanges (DEX), and interoperability with other blockchains. Fourth, there is a trade-off of computational resources and time for large-scale transaction data; thus, we believe comparing these three tokens to represent DeFi market behavior is sufficient.

3.1.2. Etherscan blockchain transaction explorer

Etherscan, a widely used blockchain explorer, serves as a valuable tool for users to search, verify, and confirm transactions on the Ethereum blockchain efficiently. It provides comprehensive transaction data, including crucial details such as transaction time, block number, sender and recipient addresses, transacted ETH value, and transaction fee (Dapp.com, 2018). Etherscan offers an API (Application Programming Interface) that allows users to access specific services, including transaction data, by obtaining an API Key, which can be acquired for free or through a paid option (Dyson, Buchanan, & Bell, 2020). As a dedicated tool for Ethereum blockchain research, Etherscan presents a user-friendly interface that simplifies the exploration of blockchain activities. Its intuitive design enables easy data sorting and filtering, facilitating investigations for users and developers in various ways.

When conducting research or analyzing the Ethereum blockchain, researchers and developers often turn to Etherscan as a valuable resource. It provides a wealth of data and comprehensive transaction details essential for their investigations and analyses. By leveraging the Etherscan API, researchers and developers can conveniently access the historical transaction data of target accounts and obtain the local structure through K-order subgraph sampling, as mentioned in one of the sources (Lin, Wu, Yuan, & Zheng, 2020). By utilizing Etherscan's rich data and functionalities, researchers can gain insights into the network dynamics, transaction patterns, and overall blockchain behavior.

3.1.3. Network analysis

Network analysis is a valuable tool for revealing relationships among

actors and analyzing the structure of various networks, including social networks (Chiesi, 2015). Nodes within these networks represent individuals or organizations, while the edges signify the connections between actors (Marsden, 2015). Over the past decade, network analysis has witnessed significant advancements and has found applications across multiple disciplines, such as computer science, biology, sociology, and economy (Barabási, 2016:12–16). Network analysis aims to enhance the understanding of system behavior by exploring the network's topology and centralities (Newman., 2010). By examining complex problems through the lens of networks, this approach sheds light on the connections among entities and the overall network structure, enabling a more profound comprehension of system behavior (Wu, Liu, Zhao, & Zheng, 2020).

For example, in the field of sociology, researchers use network analysis techniques to study how relationships between individuals impact their thoughts, attitudes, and behaviors. They examine the structure of social networks to identify key actors or influential individuals who significantly impact the overall network dynamics and outcomes. In the field of financial transaction networks, network analysis helps understand the flow of capital and identify important nodes that play a crucial role in economic activities. For instance, research on bank transaction networks aims to identify systemic risks and vulnerabilities within the financial system by analyzing the interconnectedness of banks and the propagation of shocks through the network (Alamsyah, Ramadhani, et al., 2022). In this research, we explore the transaction data from the DeFi ecosystem; thus, utilizing network analysis methodology is suitable.

3.1.4. Network measurement

Three metrics groups are used to measure the network analysis: topology, modularity, and centrality. Network topology provides insights into the relationships between nodes and the overall structure of the network. Metrics in this group are number of nodes, edges, average degree, diameter, and density. Network modularity reveals the community structures, number of groups, and group size within complex networks, uncovering connections and underlying organization patterns. Network centrality identifies influential actors based on their position, connections, and ability to control information or resource flow. Degree centrality and betweenness centrality are commonly employed metrics for centrality analysis. Table 2 provides a comprehensive overview of the measured network properties and their

Table 2
Network Metrics Explanation.

Network Measurement	Explanation
Number of Nodes	Measure the number of entities or actors or wallets present in a network
Number of Edges	Measure the number of relationships or connections between nodes in a network.
Average Degree	Measure the average number of connections that each node in a network has. It provides insights into the network's interconnectedness and information flow.
Diameter	Measure the maximum distance between any two nodes in a network. This measure provides valuable information about a network's overall size and connectivity.
Density	Measure the level of connectivity in a network, using the proportion of actual connections to possible connections. This measure indicates how closely connected the nodes in a network are to each other, providing insights into the overall efficiency and robustness of the network.
Modularity	Quantifies the extent to which a network can be divided into distinct communities or groups. It also measures the number and the size of the group.
Degree Centrality	Measure node importance by the number of connections a node has.
Betweenness Centrality	Measures node importance based on the number of shortest paths between any nodes that pass through that particular node.

explanations. (Alamsyah, Ramadhani, et al., 2022; Barabási, 2016; Newman, 2010).

3.1.5. DeFi transaction network

Choi (2023) emphasizes the significance of addresses in enabling transactions on the blockchain network. The address serves as a unique identifier that possesses an essential position when conducting transactions. The wallet is categorized based on its service type to comprehensively understand the diverse range of addresses in DeFi transactions (Cong & Xiao, 2021). We then look up the wallet address to wallet information in Etherscan explorer. We present each wallet address type explanation in Table 3. It shows the address classification based on the sector/industry/service to which they belong to.

Network analysis allows us to explore the topological, centrality, and modularity properties of the DeFi transaction network. Transactions within this network involve the encrypted transfer of ownership between addresses, known as payloads (Chen et al., 2020). In the transaction graph, nodes represent entity wallets, while directed edges signify specific transactions from source wallets to target wallets. By analyzing the transaction network, we gain valuable insights into the movement of DeFi addresses over a given period, offering a comprehensive understanding of address behavior (Fleder et al., 2014). The analysis of blockchain data provides cryptocurrency market participants with information to comprehend past and future market events, leading to increased market efficiency (Ante, Fiedler, & Strehle, 2021).

3.2. Research process

The research process consists of several steps: data collection, data preparation, network construction, network analysis, and wallet address classification. Network analysis plays a crucial role in calculating and comparing the structure of networks (Yu & Ma, 2020). The research workflow begins with data collection from Etherscan (*etherscan.io*) to gather transaction data. Next, we prepare the transaction data by choosing suitable features to construct the network. Then, we model the transaction data into DeFi transaction networks, which is the network construction step.

In network analysis, we divide into three substeps: First, we use network topology to measure the number of wallets addresses in a token transaction network, number of transactions, average transactions per wallet address, transaction network diameter, and network density; Second, we employ network modularity to finding transaction clusters; Third, we employ network centrality to identify influential wallet

Table 3
Wallet Address Classification.

Address Type	Explanation
Exchange	Exchange address associated with a service, industry, or sector that facilitates the exchange, sale, purchase, and trade of various digital assets, including tokens, cryptocurrencies, fiat currencies, and other related assets. Transactions can be conducted using smart contracts or other automated means.
Platform	Refers to services, industries, or sectors that utilize blockchain technology to solve industry problems. Exchange categories can also be considered as service platforms, but we provide a more precise classification. For instance, an industry that falls under this category is a service that reduces transaction costs, enhances transaction confirmation speed, and provides other related solutions.
Individual	Refers to address for sending and receiving assets on a blockchain network, accessible only through the owner's private key pairs. This feature ensures the security and integrity of assets and transactions. "Individual address" and "EOA" or "Wallet Address" are interchangeable terms for this address type.
Money market	This address type is associated with services or industries that manage funds through digital asset lending, borrowing, derivatives, and receiving financial assets. Aave, Compound, and Cream Finance are examples of money market service providers.

addresses. Next, we classify wallet addresses according to the classification in Table 3, which is essentially node classification. The research workflow illustration is presented in Fig. 1.

3.2.1. Data collection

A total of 5,802,742 transactions spanning a year (January 2022 to January 2023) were collected from the *etherscan.io* website. This dataset includes transaction data for DAI, UNI, and WBTC tokens. We utilized the Ethereum datafarm, a Python library developed explicitly for web scraping *etherscan.io* transactions, to gather the wallet address and its transaction. For a comprehensive breakdown of the transaction data for each token, please refer to Table 4.

3.2.2. Data preparation

Analyzing transaction data effectively requires preprocessing the raw data. The initial transaction history data includes 11 features, as outlined in Table 5. These features include address, block number, timestamp, transaction hash, transaction index, gas price, gas used, log index, and amount (Tables 6a and 6b). We filter to only two features to construct the network: the sender's (from) and receiver's (to) addresses, displayed in Table 7. For practicality, we only display a partial part of the addresses. The processed data constructs a transaction network, with addresses serving as nodes and transactions acting as edges (Alamsyah, Ramadhani, et al., 2022). We will use the data preparation result to generate a graph or network construction process.

3.2.3. Network construction

During the network construction phase, mapping of the source node is performed based on the sender address, while mapping of the target node is based on the receiver address. We utilize Python-based NetworkX and RAPIDS modules to apply the network analysis (Hricik, Bader, & Green, 2020; Huynh & Barthelemy, 2022). NetworkX, a popular Python library, offers flexible and user-friendly tools to create, analyze, and visualize complex networks or graphs. These mathematical representations of relationships between objects serve as valuable models for various real-world systems, including social networks, transportation systems, and biological networks (Dörpinghaus, Klante, Christian, Meigen, & Düing, 2022; Goldenberg, 2019). RAPIDS is an open-source framework optimized for accelerating data science and machine learning tasks by leveraging NVIDIA GPUs. It is not a single tool but a suite of GPU-accelerated libraries and APIs supporting end-to-end data science workflows. It is widely adopted for high-performance, large-scale data analysis, and machine learning, and it excels in domains with massive datasets and complex data science requirements, such as finance, healthcare, and cybersecurity. RAPIDS seamlessly integrates with other machine learning and deep learning frameworks, enhancing its utility in the data science and AI landscape, especially when combined with NVIDIA GPU hardware (Hricik et al., 2020; Schmitt, 2020).

Upon completing the construction of the transaction network, we proceed with a comprehensive network analysis as delineated in Sub-section 3.1.4. This analysis encompasses the measurement of network topology, modularity, and centrality metrics. A detailed exposition of each network metric is provided in Table 2. Utilizing the NetworkX library within Python, we execute commands to calculate the number of nodes and edges, gauge the average degree, assess network density, detect transaction clusters through network modularity, and ascertain the prominence of wallets based on degree centrality and betweenness centrality metrics. We conduct these measurements for DAI, UNI, and WBTC tokens, and subsequently draw comparisons across these networks. The comparative analysis forms the bedrock for our ensuing discussion and interpretation. For the visualization of the expansive transaction network, we employ Gephi 0.10.1, a sophisticated network visualization application. Gephi facilitates an in-depth exploration of the network structure, integrating advanced features such as the giant component filter and a degree range option, set with a threshold

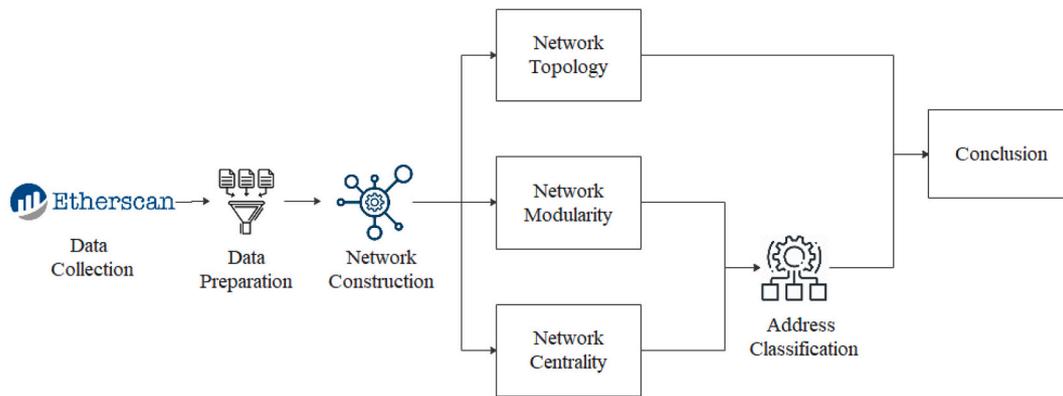


Fig. 1. Research workflow.

Table 4
Transactions data proportion for each token.

Token	Number of Transactions
DAI	3,664,182
UNI	589,036
WBTC	1,549,524
Total	5,802,742

Table 7
Data Structure After Data Preparation.

from	to
0x5d188...	0xb939c...
0xdf97...	0x28c6c...
0x6dc66...	0x9008d...
0x9008d...	0xd3d2e...

Table 5
Transaction Data Information.

Transaction Information	Explanation
Address	The address of the token under analysis.
blocknumber	The block number in which the transaction occurred
timestamp	The time when a transaction is executed and recorded in the blockchain
txhash	Useful for tracking and tracing the status of a transaction
txindex	Indicates the position of a transaction within the Ethereum block sequence, making it easier to track in the transaction history
gas_price	The gas price for a transaction, measured in Gwei, is determined by market supply and demand.
gas_used	The gas (energy) consumption of the transaction.
logindex	Indicates the position of log in log sequence of the particular block on the blockchain
from	The address of the sender
to	The address receiver
amount	The amount of ETH to be transferred from the sender to the recipient is denominated in WEI, where 1 ETH equals 1e+18 WEI.

Table 6a
Example Data Before Data Preparation.

address	blocknumber	timestamp	txhash	txindex
0x1f984...	14013197	1,642,291,219	0x920e0...	116
0x1f984...	14013205	1,642,291,323	0x7a743...	28
0x1f984...	14013222	1,642,291,600	0 × 59382...	4
0x1f984...	14013222	1,642,291,600	0 × 59382...	4

Table 6b
Example Data Before Data Preparation (continued).

gas_price	gas_used	logindex	from	to	amount
1.38E+11	52418	152	0x5d188...	0xb939c...	1.95E+20
1.54E+11	35318	40	0xdf97...	0x28c6c...	6.07E+20
1.24E+11	294682	29	0x6dc66...	0x9008d...	2.42E+20
1.24E+11	294682	31	0x9008d...	0xd3d2e...	2.38E+20

minimum of 20, to refine our visual representation of the network's intricate topology.

3.2.4. Address classification

The steps in address classification primarily involve searching for the wallet address ID to find public tags or other information on Etherscan that provides details about the entity associated with the wallet. This process can be challenging due to the pseudonymous nature of blockchain transactions. Various methods are used to determine the identity behind an address. For instance, Etherscan assigns public name tags to specific addresses linked with known entities like cryptocurrency exchanges or reputable companies. These public tags form part of a broader initiative aimed at identifying and analyzing activities carried out by different participants. They provide valuable insights into a wallet's owner or purpose, often created by its owner or other users within the community (Etherscan.io., 2023). Another option is to analyze the transaction history and behavior of an address. By examining patterns and interactions with known entities, it may be possible to deduce the type of entity that controls the address. In some cases, utilizing third-party services and analytics platforms can help identify addresses by analyzing transaction patterns and other blockchain data. Our approach relies on publicly available information, including public tags, transaction history analysis, and inference from interactions with known addresses. Once we have identified the entities associated with specific addresses, we proceed to classify them based on predefined criteria outlined in Table 3.

On centrality measurements, our manuscript presents the ranking of the top 10 wallets due to space limitations and considerations of representatives' top 10 wallet behavior in guiding market dynamics. This consideration is based on network analysis, especially in market dynamics, where network growth and shrink depend on a few actors, which we identify in the centralities metrics (Barabási, 2016; Newman, 2010). However, we also have a comprehensive list that includes rankings for all centrality metrics. By running centralities calculations for both degree and betweenness, we obtain the centrality values for each wallet address. These metrics illustrate which wallets are highly engaged in the network analysis. These influential wallets play an active role in our analysis, allowing us to focus on their interactions and streamline our workflow for greater efficiency. We can extract valuable

insights from these significant contributors within the ecosystem, prioritize their actions, and potentially expand our analysis to encompass a wider scope if necessary.

4. Result and discussion

4.1. Result

The following section presents the results and analysis outcomes of network topology, network modularity, and network centrality of DAI, UNI, and WBTC. Table 8 shows each token's network topology metrics values: the number of nodes and edges, and the average degree, diameter, and density value. It highlights the varying characteristics of token networks in terms of market size, actors (wallets) interaction or involvement in transactions, and their behavior. Table 9 provides modularity measurements that explain network grouping quality and the number of communities. Additionally, Table 10 shows filtered modularity results of the two biggest communities on each network. The top 10 ranks of degree and betweenness centrality and their values are shown in Table 11, equipped with wallet address classification.

These tables effectively summarize the findings of transaction network analysis and comprehensively understand the network's characteristics. Network analysis is a powerful tool to explain market behavior, since the market can be conceptualized as a complex system where various actors (like individuals, organizations, or countries) and assets (like stocks, commodities, or currencies) interact. Some network analysis's immediate applications are mapping actor relationships, detecting communities, identifying important actors in the market, and describing the interconnectedness of the market and potential systematic risks. Network analysis could be used to identify the structural hole, which explains if an intermediary actor becomes absent, then the network could be disconnected. A more advanced application could trace how market network dynamic evolves over time, giving insight into the changing nature of market relationship. The cascading effect could also be measured to see how behavior or shock affects the network. In the following subsection discussion, we focus on the immediate application of network analysis.

In network topology, we focus on the number of participants and interactions, thus explaining the immediate impact of the network market. In network modularity, we discuss grouping quality, which later can explain the decentralization character of the network. In network centrality, we identify dominant actors, whose roles are essential as centralized power, which also explains the decentralization nature of the DeFi network.

4.2. Discussion

4.2.1. Network topology

Through a comprehensive analysis of multiple transaction network properties, including node, edge, average degree, diameter, and density, DAI surpasses the other tokens in terms of transaction network properties. DAI achieves the highest values in two of the five properties; it emerges as the leader with a higher number of nodes and edges, indicating the largest participant, market presence, and more extensive transaction engagement. We can also translate as a higher number of

Table 8
Network Topology Measurement Result.

Network Topology	Token		
	DAI	UNI	WBTC
Node	539.932	192.291	102.115
Edges	1.231.908	261.076	264.609
Average Degree	1671	1409	2519
Diameter	61	46	60
Density	0,00000845	0,00001412	0,00000755

Table 9
Network Modularity Measurement Result.

Network Modularity	Token		
	DAI	UNI	WBTC
Value	0.625	0.687	0.475
Number of Communities	4538	5804	936

Table 10
Network Modularity Group Size.

Token	Nodes	Edges	Modularity rank 1 (%)	Modularity rank 2 (%)
DAI	5229	92,574	30,37	16,77
UNI	459	4765	42,27	22,88
WBTC	1016	21,193	30,12	27,17

wallet addresses involved and a significant level of transaction between addresses. The number of addresses engaged in DAI transactions indicates active participation from a substantial user base, leading to a more robust network infrastructure. More addresses involved reflect DAI's growing trust and confidence as a reliable token within the crypto and DeFi market. We can infer this phenomenon by explaining that factors like value stability, liquidity, and compatibility might increase user participation in DAI. The growing number of DAI users generates positive feedback and exponentially attracts additional users, merchants, and service providers to accept and support DAI (Morales, Somin, Altshuler, & Pentland, 2020). This phenomenon called the network effect, is indicated by the increasing number of edges between participants through direct transactions. DAI's liquidity and market efficiency are enhanced through its interconnectedness, offering additional pathways for transactions and information exchange. As the number of pathways continues to expand, DAI's ecosystem will thrive with a growing number of pathways, fostering plentiful transaction opportunities and cultivating a dynamic community.

On the other hand, UNI demonstrates an impressive shortest diameter measurement, suggesting easy accessibility among market participants compared to DAI and WBTC. The smaller value of this metric means that each market participant is connected via the shortest distance possible. It indicates that UNI has a relatively more compact and tightly connected structure than DAI and WBTC. In other words, UNI tends to have shorter paths and distances between addresses in the network. The smaller transaction network diameter signifies strong connectivity and higher direct connections among UNI participants, suggesting that the transactions within the UNI network can be faster, more efficient, and more closely interconnected. Unlike UNI and WBTC, DAI's largest transaction network size indicates the longest short path between two addresses. A larger network diameter means DAI has a more extensive and diverse user base, which is not well connected to each other.

While WBTC stands out with the highest average degree value of 2.519, surpassing both DAI and UNI. It implies that, on average, WBTC each market participant involves more transactions. Even though WBTC has the smallest wallet address involved in the transaction network, they transact more actively. However, it is important to note that the density values for all three networks are almost zero, indicating sparse connections, which is normal for natural network analysis. These observations underline the importance of optimizing network efficiency and increasing transactions to foster more robust and interconnected market dynamics.

4.2.2. Network modularity

The modularity analysis is employed to assess the grouping quality of the transaction network, identify wallet address groups, and measure the group size. A higher modularity value indicates a more modular network, which means a higher number of transactions between group

Table 11
Top 10 Network Centrality Measurement Result.

Token	Network Centrality Metrics					
	Degree Centrality			Betweenness Centrality		
	Address	Score	Category	Address	Value	Category
DAI	0 × 60594...	58,209	Exchange	0x28c6c...	0.133654	Exchange
	0 × 50382...	56,976	Exchange	0 × 50382...	0.114073	Exchange
	0x74de5...	51,394	Exchange	0 × 60594...	0.096396	Exchange
	0x28c6c...	43,286	Exchange	0x74de5...	0.089256	Exchange
	0x5777d...	33,181	Exchange	0x5777d...	0.059072	Exchange
	0xa478c...	24,712	Exchange	0xa9d1e...	0.045404	Exchange
	0xa9d1e...	24,086	Exchange	0xa478c...	0.035118	Exchange
	0xc3d03...	16,667	Exchange	0x2faf4...	0.028407	Exchange
	0xffec0...	16,632	Money Market	0xffec0...	0.026366	Money Market
	0x2faf4...	15,026	Exchange	0xf16e9...	0.024793	Exchange
WBTC	0x4585f...	25,272	Exchange	0x4585f...	0.202131	Exchange
	0x74de5...	10,732	Exchange	0x28c6c...	0.140569	Exchange
	0x28c6c...	9599	Exchange	0x74de5...	0.091328	Exchange
	0x99ac8...	8520	Exchange	0x3cd75...	0.053011	Exchange
	0xcbcdf...	7465	Exchange	0x9ff58...	0.049341	Money Market
	0x9ff58...	7218	Money Market	0x99ac8...	0.043066	Exchange
	0x3cd75...	5037	Exchange	0xbb2b8...	0.04249	Exchange
	0xbb2b8...	4973	Exchange	0xcbcdf...	0.037893	Exchange
	0xceff5...	4278	Exchange	0x2faf4...	0.037257	Exchange
	0x9a772...	4146	Exchange	0xceff5...	0.029612	Exchange
UNI	0xb739d...	18,710	Exchange	0x28c6c...	0.081248	Exchange
	0x1d420...	16,835	Exchange	0xb739d...	0.071165	Exchange
	0xa9d1e...	10,391	Exchange	0x1d420...	0.059225	Exchange
	0x74de5...	10,107	Exchange	0x74de5...	0.036186	Exchange
	0x28c6c...	9493	Exchange	0xd3d2e...	0.034379	Exchange
	0xd3d2e...	7813	Exchange	0xa9d1e...	0.034155	Exchange
	0x2faf4...	7473	Exchange	0x2faf4...	0.025872	Exchange
	0xdfd52...	7428	Exchange	0x6cc5f...	0.022413	Exchange
	0x21a31...	7224	Exchange	0xf16e9...	0.01991	Exchange
	0xfaa31...	5525	Exchange	0x4c600...	0.0179	Individual

members than another. Through the group identification process, we learn how transactions are concentrated between the three tokens. According to the modularity analysis, UNI's network exhibits a slightly higher value than DAI and a significantly higher value than WBTC (Tables 9 and 10). UNI shows a higher frequency of transactions within a specific group, indicating a higher level of interactions among participants within the group. We could infer that the UNI network dominates common interest among market participants, actively participates in similar DeFi applications, or other influences promoting group transactions. In contrast, the modularity analysis reveals that WBTC

demonstrates a lower level of modularity. A lower transaction frequency between groups indicates potential cross-group interaction barriers or limitations, such as varying interests and preferences (Mazza, Cola, & Tesconi, 2023). We could infer that WBTC has a more interconnected between group and less segregated network structure. WBTC transaction networks are evenly distributed without forming highly distinct or segregated communities.

A high level of modularity transaction network suggests that the group includes risks or actions that potentially endanger their peers; consequently, if a person in the group engages in risky behavior, it

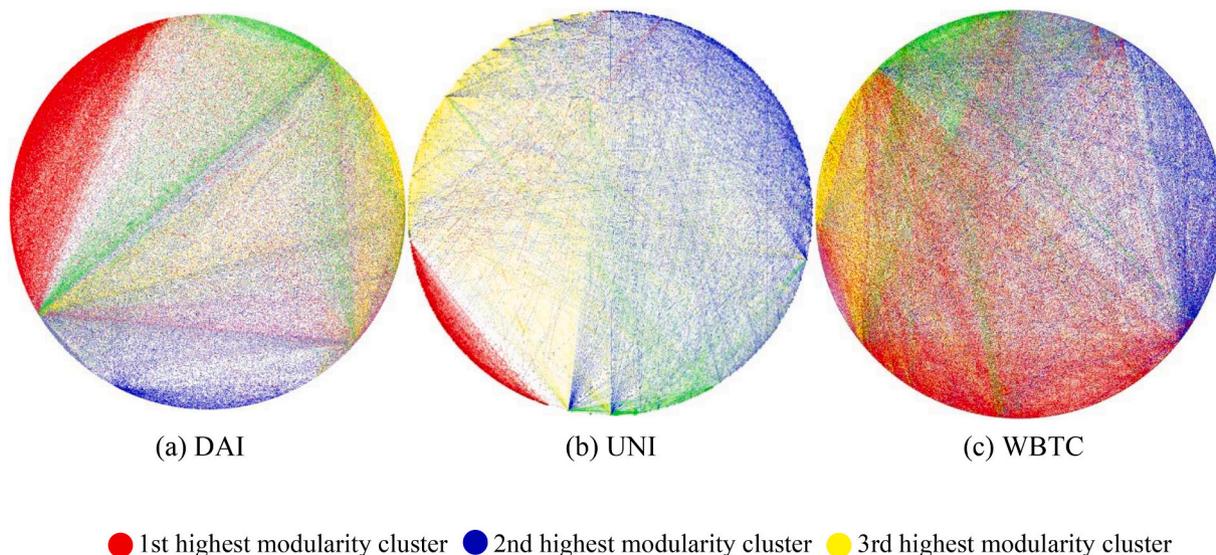


Fig. 2. Modularity Transaction Network.

significantly impacts others who are part of the same group. Another implication of grouping is that new participants tend to connect with those already well-connected. This phenomenon leads to a situation where the rich-get-richer effect. It can further enhance and enlarge the existing modules, making them even stronger and bigger. As the network grows, the popular exchange experiences a rapid increase in fame. Furthermore, the transaction behavior of each group studies helps us comprehend the details of each group's transaction behavior. This interconnectedness implies a broader range of transactional interactions can be categorized. A low modularity value can signify a more decentralized transaction network, which we supposedly expect to see in the DeFi topological structure.

We provide network modularity visualization in Fig. 2. The giant filter and degree range are utilized to visualize transaction networks effectively and efficiently since it is impossible to visualize millions of transactions in a single visualization. The giant component filter narrows down the addresses with strong connections within the network and eliminates unconnected nodes. The degree range filter is integrated as a sub-filter of the giant component filter. For precise analysis, nodes with a minimum of twenty connections are filtered out and analyzed without specifying a maximum value. Market participants are categorized using different color codes to represent their respective groups. The largest group on each token is represented by the red color, with UNI at 42.27%, DAI at 30.37%, and WBTC at 30.12% (as shown in Table 10). Dark blue indicates the second-ranked, while yellow represents the third-ranked. The group size percentage indicates the proportion of wallet addresses within a group compared to the total addresses in the transaction network, offering valuable insights into address concentration within specific groups and distribution across different groups. The group with the highest modularity percentage consistently includes exchange and platform address types. These address types are essential components in the DeFi ecosystem as they actively purchase, sell, and exchange DeFi network tokens. They also play a significant role as key players and infrastructure providers, facilitating transactions and ensuring sufficient liquidity for traders and investors. The presence of these address types within highly modular clusters signifies their crucial contribution to most DeFi transaction networks.

4.2.3. Network centrality

Degree centrality ranks show the highest wallet address involved in the transaction. The score reveals how many times they are actively in the transaction network. Betweenness centrality measures the importance of wallet address as the role of intermediaries. They become bridges or hubs, if many shortest paths pass them between any wallet address in the network. Higher betweenness centrality means their roles are likely an intermediary. Table 11 shows the top 10 wallet addresses based on degree and betweenness centrality ranks and their respective role based on wallet address classification. These centrality calculations help to identify the key players for each network token. In degree centrality analysis, we discover that the key address for the DAI transaction network is $0 \times 60594\dots$, for UNI, it is $0xb739d\dots$, and for WBTC, it is $0x4585f\dots$. Additionally, based on betweenness centrality, we identified the addresses with the highest values in the DAI network as $0x28c6c\dots$, for UNI, it is $0x28c6c\dots$, and for WBTC, it is $0x4585f\dots$. The difference score between network tokens shows us how centralized the network is compared to each other. Here, UNI proves to have a lower betweenness centrality value, indicating node roles as intermediary is less visible than any other network.

Exchanges hold the highest influence among addresses, followed by smaller proportions in the money market, platform, and individual categories. It shows how exchanges are crucial in empowering market activities and nurturing a vibrant ecosystem. Exchanges could significantly impact the network's growth and shrink, which is counterintuitive to the decentralized nature of DeFi that we expect. Network centrality analysis is used to identify the key address for each token and

determine which addresses play a crucial role in the transaction network, mapping interconnections between addresses and relationships between addresses, revealing outliers in transaction activities, providing valuable insights for optimizing fund transfers, and network performance, leading to improvements in overall performance especially for transaction security, foster stability, and reduce risks. Ultimately, it provides valuable knowledge to market participants, regulators, and innovators to enhance their understanding of previously undisclosed elements.

5. Conclusion

We have analyzed the DeFi transaction network and highlighted the three largest Ethereum-based DeFi tokens: DAI, UNI, and WBTC. Those three tokens have different characteristics in nature: UNI, which is a native governance token in the Uniswap platform; DAI, which is a general stablecoin and can be used outside the DeFi use case; and WBTC, which Bitcoin backs as collateral. Although the three tokens are considered the most successful DeFi; DAI has the highest market size; WBTC has the best decentralized nature, and UNI has a better (smaller) network reach, indicating the dominant presence of intermediary (exchange). The study unveils hidden DeFi market structures, such as dominant actors, grouping, and asset movement within the network. The findings help market participants and innovators optimize the DeFi infrastructure based on network structure to ensure stability and mitigate risks, including a centralized nature.

With 50,80% shares of the DeFi market in 2022, these three tokens play a crucial role in shaping the DeFi landscape. We offer a comprehensive transactions network overview in the DeFi ecosystem, contributing to our understanding of the whole ecosystem. In this study, we learn that DeFi transaction patterns and network structure can help identify address participants, transaction frequencies, transaction sizes, relationships between addresses, address key players, address hubs, and transaction clusters, which can be valuable for understanding market dynamics, reveal patterns in the flow of transactions, streamline processes, and improve operational efficiency. Understanding the network mechanism could lead to a deeper understanding of DeFi market operation. Support decision process for stakeholders to streamline processes, enhancing liquidity and enabling quick and efficient capitalization, triggering more innovation. It could help to build a more robust and attractive environment for market participants, promoting the growth and sustainability of the DeFi ecosystem.

We propose a deeper network analysis examination for future research. First, tracing how market dynamics evolve over time, each network metric is measured as a time series, which could explain the changing nature of market relationships and segmentation. Second, network structural hole identification explains the importance of intermediary actors to the extent that affects the network integrity if the actor is absent. Third, measure the cascading effect to see the network behavior after the shock. Another recommendation could be to extend the data collection period for representative analysis. Lastly, we could expand the methodology to other crypto assets like NFTs, and cryptocurrency.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

References

- Alamsyah, A., Hakim, N., & Hendayani, R. (2022). Blockchain-based traceability system to support the Indonesian halal supply chain ecosystem. *Economies*, 10(6). <https://doi.org/10.3390/economies10060134>
- Alamsyah, A., Ramadhani, D. P., Kristanti, F. T., & Khairunnisa, K. (2022). Transaction network structural shift under crisis: Macro and micro perspectives. *Economies*, 10(3). <https://doi.org/10.3390/economies10030056>
- Alamsyah, A., & Syahrir, S. (2023). The taxonomy of Blockchain-based Technology in the Financial Industry. *F1000Research*, 12, 457. <https://doi.org/10.12688/f1000research.133518.2>
- Ali Syed, T., Alzahrani, A., Jan, S., Siddiqui, M. S., Nadeem, A., & Alghamdi, T. (2019). A comparative analysis of Blockchain architecture and its applications: Problems and recommendations. *IEEE Access*, 7, 176838–176869. <https://doi.org/10.1109/ACCESS.2019.2957660>
- Ante, L., Fiedler, I., & Strehle, E. (2021). The impact of transparent money flows: Effects of stablecoin transfers on the returns and trading volume of bitcoin. *Technological Forecasting and Social Change*, 170. <https://doi.org/10.1016/j.techfore.2021.120851>
- Ao, Z., Horvarth, G., & Zhang, L. (2023). *Is decentralized finance decentralized? A social network analysis of the Aave protocol on the Ethereum blockchain*. ArXiv, arXiv:2206.08401v3.
- Bank Indonesia. (2020). Sistem Pembayaran & Pengelolaan Uang Rupiah. <https://www.bi.go.id/id/fungsi-utama/sistem-pembayaran/default.aspx>.
- Barabási, A. L. (2016). *Network science*. Cambridge University Press.
- Binance. (2020, August 24). What is uniswap and how does it work? Binance academy. <https://academy.binance.com/en/articles/what-is-uniswap-and-how-does-it-work#How-Does-Uniswap-Work>.
- Binance. (2020, December 4). What Is MakerDAO (DAI) ? Binance academy. <https://academy.binance.com/en/articles/a-guide-to-makerdao-and-dai>.
- Chang, A., El-Rayes, N., & Shi, J. (2022). Blockchain Technology for Supply Chain Management: A comprehensive review. *FinTech*, 1(2), 191–205. <https://doi.org/10.3390/fintech1020015>
- Chen, J., Xia, X., Lo, D., & Grundy, J. (2022). Why do smart contracts self-destruct? Investigating the Selfdestruct function on Ethereum. *ACM Transactions on Software Engineering and Methodology*, 31(2). <https://doi.org/10.1145/3488245>
- Chen, W., Zhang, T., Chen, Z., Zheng, Z., & Lu, Y. (2020). Traveling the token world: A graph analysis of Ethereum ERC20 token ecosystem. In *The web conference 2020 - proceedings of the world wide web conference, WWW 2020* (pp. 1411–1421). <https://doi.org/10.1145/3366423.3380215>
- Chiesi, A. M. (2015). Network analysis. In *International encyclopedia of the Social & Behavioral Sciences* (2nd ed., pp. 518–523). Elsevier Inc. <https://doi.org/10.1016/B978-0-08-097086-8.73055-8>
- Choi, K. (2023). What is an Ethereum address. <https://info.etherscan.com/what-is-a-n-ethereum-address/>.
- CoinGecko. (2022). Top 100 DeFi coins by market capitalization. <https://www.coingecko.com/en/categories/decentralized-finance-defi>.
- Coinmarketcap. (2022, December 31). Top DeFi tokens by market capitalization. <https://coinmarketcap.com/view/defi/>.
- Coinmarketcap. (2023). Top DeFi tokens by market capitalization. <https://coinmarketcap.com/view/defi/>.
- Cong, L. W., & Xiao, Y. (2021). Categories and functions of crypto-tokens. In *The Palgrave handbook of FinTech and Blockchain* (pp. 267–284). Springer International Publishing. https://doi.org/10.1007/978-3-030-66433-6_12.
- Damalas, G., & Stafford, A. (2021). How will decentralized finance shake up your industry?. https://www.ey.com/en_nl/consulting/how-will-decentralized-finance-shake-up-your-industry.
- Dapp.com. (2018). Dappedia | A useful tool to better navigate on the ethereum blockchain. <https://medium.com/dapp-com/dappedia-a-useful-tool-to-better-navigate-on-the-ethereum-blockchain-etherscan-io-f2ca28e09e49>.
- Dasgupta, S., & Grover, P. (2019). Critically evaluating SWIFT's strategy as a monopoly in the fintech business. *International Journal of Innovative Technology and Exploring Engineering*, 8(12), 3839–3844. <https://doi.org/10.35940/ijitee.L3355.1081219>
- Dehmer, M., & Basak, C. S. (2012). In M. Dehmer, & S. C. Basak (Eds.), *Statistical and machine learning approaches for network analysis*. Wiley. <https://doi.org/10.1002/9781118346990>.
- Deloitte. (2017). *Using blockchain to drive supply chain innovation*.
- Diyana. (2023, January 10). What Is Wrapped Bitcoin (wBTC) And How Does It Work? CoinGecko. <https://www.coingecko.com/learn/what-is-wrapped-bitcoin-wbtc-and-how-does-it-work>.
- Dörpinghaus, J., Klante, S., Christian, M., Meigen, C., & Düing, C. (2022). From social networks to knowledge graphs: A plea for interdisciplinary approaches. *Social Sciences & Humanities Open*, 6(1), Article 100337. <https://doi.org/10.1016/j.ssho.2022.100337>
- Dyson, S. F., Buchanan, W. J., & Bell, L. (2020). Scenario-based creation and digital investigation of ethereum ERC20 tokens. *Forensic Science International: Digital Investigation*, 32. <https://doi.org/10.1016/j.fsidi.2019.200894>
- Eagle, N., Macy, M., & Claxton, R. (2010). Network diversity and economic development. *Science*, 328(5981). <https://doi.org/10.1126/science.1186605>
- Ervin, E. (2018, August 16). Blockchain technology set to revolutionize global stock trading. *Forbes*. <https://www.forbes.com/sites/ericervin/2018/08/16/blockchain-technology-set-to-revolutionize-global-stock-trading/?sh=119097644e56>.
- Etherscan.io. (2023). *Address name tag & Private Note*. Information Center.
- Farrington, R. (2021). *Explaining DeFi And How It Will Revolutionize Financial Services*. <https://www.forbes.com/sites/robertfarrington/2021/03/23/explaining-defi-and-how-it-will-revolutionize-financial-services/?sh=1d93c44b1d08>.
- Fleder, M., Kester, M. S., & Pillai, S. (2014). Bitcoin Transaction Graph Analysis. <http://bitcoin.org/en/download>.
- Frick, T. A. (2021, December 4). Tokenized assets in Switzerland – New structures and standards - fin tech - Switzerland. Mondaq. <https://www.mondaq.com/fin-tech/1138726/tokenized-assets-in-switzerland-new-structures-a>.
- Friesendorf, C., & Blütener, A. (2023). *Decentralized finance (DeFi)*. Springer Nature Switzerland. <https://doi.org/10.1007/978-3-031-37488-3>
- Goldenberg, D. (2019). Social network analysis: From graph theory to applications with Python. In *Proceedings of Israeli Python conference 2019 (PyCon '19)*.
- Guo, D., Dong, J., & Wang, K. (2019). Graph structure and statistical properties of Ethereum transaction relationships. *Information Sciences*, 492, 58–71. <https://doi.org/10.1016/j.ins.2019.04.013>
- Guo, Y., & Liang, C. (2016). Blockchain application and outlook in the banking industry. In *Vol. 2, Issue 1. Financial innovation*. SpringerOpen. <https://doi.org/10.1186/s40854-016-0034-9>.
- Haleem, A., Javaid, M., Singh, R. P., Suman, R., & Rab, S. (2021). Blockchain technology applications in healthcare: An overview. *International Journal of Intelligent Networks*, 2, 130–139. <https://doi.org/10.1016/j.ijin.2021.09.005>
- Hricik, T., Bader, D., & Green, O. (2020). Using RAPIDS AI to accelerate graph data science workflows. In *2020 IEEE high performance extreme computing conference (HPEC)* (pp. 1–4). <https://doi.org/10.1109/HPEC43674.2020.9286224>
- Huynh, N., & Barthelemy, J. (2022). A comparative study of topological analysis and temporal network analysis of a public transport system. *International Journal of Transportation Science and Technology*, 11(2), 392–405. <https://doi.org/10.1016/j.ijst.2021.05.003>
- Javaid, M., Haleem, A., Singh, R. P., Suman, R., & Khan, S. (2022). A review of Blockchain technology applications for financial services. *Benchmark Transactions on Benchmarks, Standards and Evaluations*, 2(3), Article 100073. <https://doi.org/10.1016/j.tbench.2022.100073>
- Karamitsos, I., Papadaki, M., Barghuthi, N. B., & Al. (2018). Design of the blockchain smart contract: A use case for real estate. *Journal of Information Security*, 09(03), 177–190. <https://doi.org/10.4236/jis.2018.93013>
- Krawiec, R., Housman, D., & White, M. (2018). *Blockchain: Opportunities for health care*.
- Kuo, T.-T., & Ohno-Machado, L. *ModelChain: Decentralized privacy-preserving healthcare predictive modeling framework on private Blockchain networks*. ArXiv Preprint. (2018). arXiv:1802.01746.
- Leech, O. (2021, February 9). *What is Uniswap? A complete beginner's guide*. DeFi. <https://www.coindesk.com/business/2021/02/04/what-is-uniswap-a-complete-beginners-guide/>.
- Levis, D., Fontana, F., & Ughetto, E. (2021). A look into the future of blockchain technology. *PLoS One*, 16(11 November). <https://doi.org/10.1371/journal.pone.0258995>
- Liang, J., Li, L., & Zeng, D. (2018). Evolutionary dynamics of cryptocurrency transaction networks: An empirical study. *PLoS One*, 13(8), Article e0202202. <https://doi.org/10.1371/journal.pone.0202202>
- Lin, D., Wu, J., Yuan, Q., & Zheng, Z. (2020). T-EDGE: Temporal Weighted MultiDiGraph embedding for Ethereum transaction network analysis. *Frontiers of Physics*, 8, 204. <https://doi.org/10.3389/fphy.2020.00204>
- Mainelli, M., & Milne, A. (2016). *The impact and potential of Blockchain on the securities transaction lifecycle*.
- MakerDAO. (2017). *The maker protocol: MakerDAO's multi-collateral Dai (MCD) system*.
- Marsden, P. V. (2015). Network centrality, measures of. In *International encyclopedia of the Social & Behavioral Sciences* (pp. 532–539). Elsevier. <https://doi.org/10.1016/B978-0-08-097086-8.43115-6>.
- Mazza, M., Cola, G., & Tesconi, M. (2023). Modularity-based approach for tracking communities in dynamic social networks. *ArXiv*, 2302, 12759.
- Morales, A. J., Somin, S., Altshuler, Y., & Pentland, A. (2020). *User behavior and token adoption on ERC20*. ArXiv, abs/2005.12218.
- Motamed, A. P., & Bahrak, B. (2019). Quantitative analysis of cryptocurrencies transaction graph. *Applied Network Science*, 4(1). <https://doi.org/10.1007/s41109-019-0249-6>
- Nadini, M., Alessandretti, L., Di Giacinto, F., et al. (2021). Mapping the NFT revolution: Market trends, trade networks, and visual features. *Scientific Reports*, 11, 20902. <https://doi.org/10.1038/s41598-021-00053-8>
- Naggar, M. (2023). *Binance research real world assets bridge TradFi and DeFi*.
- Nasdaq. (2017, June 12). *How stock exchanges are experimenting with blockchain technology*. Nasdaq. <https://www.nasdaq.com/articles/how-stock-exchanges-are-experimenting-blockchain-technology-2017-06-12>.
- Newman, M. (2010). *Network: An introduction*. Oxford University Press.
- OKX. (2022, December 30). What Is Wrapped Bitcoin (WBTC)? OKX. <https://www.okx.com/learn/what-is-wrapped-bitcoin>.
- Peterson, K. J., Deeduvanu, R., Kanjama, P., & Mayo, K. B. (2016). *A Blockchain-based approach to health information exchange networks*.
- Qin, K., Zhou, L., Afonin, Y., Lazzaretti, L., & Gervais, A. (2021). *CeFi vs. DeFi – Comparing decentralized to decentralized finance*.
- Rejolut. (2023). Tokenization & use cases. www.rejolut.com.
- Schär, F. (2021). Decentralized finance: On Blockchain- and smart contract-based financial markets. *Review*, 103(2). <https://doi.org/10.20955/r.103.153-74>
- Schenk, C. R. (2021). The global financial crisis and banking regulation: Another turn of the wheel? *Journal of Modern European History*, 19(1), 8–13. <https://doi.org/10.1177/1611894420974252>
- Schletz, M., Cardoso, A., Prata Dias, G., & Salomo, S. (2020). How can Blockchain technology accelerate energy efficiency interventions? A use case comparison. *Energies*, 13, 5869. <https://doi.org/10.3390/en13225869>
- Schmitt, J. (2020, November). *Building an accelerated data science ecosystem: RAPIDS hits two years*. In *Data Science technical blog*.

- Spielman, A. (2016). *Blockchain: Digitally rebuilding the real estate industry*. Massachusetts Institute of Technology.
- Statista. (2022a). Number of unique addresses that either bought or sold a Decentralized Finance (DeFi) asset worldwide from December 2017 to July 4, 2022. <https://www.Statista.Com/Statistics/1297745/Defi-User-Number/>.
- Statista. (2022b). TVL (total value locked) across multiple Decentralized Finance (DeFi) blockchains from November 2018 to June 26, 2022. <https://www.statista.com/statistics/1272181/defi-tvl-in-multiple-blockchains/>.
- Tapscott, A., & Tapscott, D. (2017, March 1). How Blockchain is changing finance. *Harvard Business Review*. <https://hbr.org/2017/03/how-blockchain-is-changing-finance>.
- Tasca, P., & Tessone, C. J. (2018). Taxonomy of Blockchain technologies. *Principles of Identification and Classification*. <https://doi.org/10.2139/ssrn.2977811>
- Tran, K. C. (2022, May 17). What is wrapped bitcoin? Decrypt. <https://decrypt.co/resources/what-is-wbtc-explained-bitcoin-ethereum-defi>.
- Veuger, J. (2018). Trust in a viable real estate economy with disruption and blockchain. *Facilities*, 36(1/2), 103–120. <https://doi.org/10.1108/F-11-2017-0106>
- Voshmgir, S. (2020). *Token economy: How the Web3 reinvents the internet* (2nd ed.). Token Kitchen.
- WBTC. (2023). WHAT IS WBTC? WBTC. <https://wbtc.network/>.
- Wharton Blockchain and Digital Asset Project, & World Economic Forum. (2021). *DeFi Beyond the Hype: The Emerging World of Decentralized Finance*.
- Wu, B., & Duan, T. (2019). The application of Blockchain Technology in Financial markets. *Journal of Physics: Conference Series*, 1176(4). <https://doi.org/10.1088/1742-6596/1176/4/042094>
- Wu, J., Liu, J., Zhao, Y., & Zheng, Z. (2020). *Analysis of Cryptocurrency transactions from a network perspective: An overview*. <https://doi.org/10.1016/j.jnca.2021.103139>
- Xu, J., Guo, S., Xie, D., & Yan, Y. (2020). Blockchain: A new safeguard for Agri-foods. *Artificial Intelligence in Agriculture*, 4, 153–161. <https://doi.org/10.1016/j.aaaa.2020.08.002>
- Yu, G., Liu, R. P., Zhang, J. A., & Guo, Y. J. (2022). *Tamperproof IoT with Blockchain*. *ArXiv E-Prints*. <https://doi.org/10.48550/arXiv.2208.05109>
- Yu, J. K., & Ma, J. Q. (2020). Social network analysis as a tool for the analysis of the international trade network of aquatic products. *Aquaculture International*, 28(3), 1195–1211. <https://doi.org/10.1007/s10499-020-00520-5>