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DECENTRALIZED FINANCE: PRINCIPLES OF FUNCTIONING, INFRASTRUCTURE, RISKS

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Lukianchuk D. Yu. Decentralized Finance: Principles of Functioning, Infrastructure, Risks

The article analyzes the differences between centralized and decentralized exchanges in the cryptocurrency market. The author notes the impact of bankruptcies of centralized representatives who provided services in the cryptocurrency market on the interaction of users with decentralized finance instruments. The publication considers the key representatives of decentralized finance, their capitalization, available capital, and technological developments. It substantiates the advantages and risks of using decentralized finance instruments and studies the differences between centralized, decentralized, and algorithmic stablecoins. To assess the capitalization of decentralized finance instruments, the asset value indicator TVL (Total Value Locked) is used. TVL represents the amount of assets currently placed in a particular decentralized finance instrument or protocol. The RWA narrative is significant in the crypto space as it demonstrates increased interconnectedness. DeFi, previously isolated from TradFi, has now become an integral part of a more holistic financial ecosystem. Blockchain technology has demonstrated its potential for transformation through real-world use cases. Real-world assets (RWAs) are an attractive option due to the large traditional finance market. While they offer benefits such as portfolio diversification and enhanced returns, it is crucial to mitigate default risk. Platforms like Goldfinch have a proven track record. Tokenizing RWAs can increase market participation and financial inclusivity. The study's results indicate significant development of decentralized finance instruments over the past three years. This is evidenced by the amount of capital invested in these instruments and the number of users, despite the technological and regulatory risks associated with them. The study's conclusions indicate that despite the technological novelty, users are increasingly interested in interacting with decentralized finance instruments. However, users face difficulties in understanding how these instruments work and in gaining experience with these products. The comparative analysis by Saif Ahmed Abdulhakeem and Qiuling Hu titled "CeFi vs. DeFi — Comparing Centralized to Decentralized Finance" systematically contrasts Centralized Finance (CeFi) with Decentralized Finance (DeFi) across legal, economic, security, privacy, and market manipulation dimensions. It aims to provide a structured approach for distinguishing between CeFi and DeFi services, emphasizing DeFi's transparency and user control advantages. However, unresolved issues in decentralized finance, such as regulatory frameworks and risk assessment, necessitate further research. The study also underscores the importance of improving user experience design and overcoming adoption challenges for DeFi. In their academic discourse titled "Powered by Blockchain Technology, DeFi (Decentralized Finance) Strives to Increase Financial Inclusion of the Unbanked by Reshaping the World Financial System," Abdulhakeem and Hu analyze DeFi's potential to enhance financial inclusion for the unbanked. They highlight the pivotal role of blockchain, particularly Ethereum, in enabling DeFi. While acknowledging DeFi's decentralization benefits, the article suggests it as a complement rather than a replacement for traditional finance. It advocates for future research on integrating DeFi with global banking systems and improving user interface and security. Overall, while recognizing DeFi's transformative potential, the article underscores the need for ongoing research to address challenges and integrate DeFi into mainstream finance seamlessly.

Keywords: *decentralized finance, centralized exchanges, decentralized exchanges, stablecoins, smart contracts, blockchain, real world assets.*
Tabl.: *3.* ***Bibl.:*** *44.*

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Лук'янчук Д. Ю. Децентралізовані фінанси: принципи функціонування, інфраструктура, ризики

У статті проаналізовано відмінності між централізованими та децентралізованими біржами на ринку криптовалют. Автор зазначає вплив банкрутств централізованих представників, які надавали послуги на ринку криптовалют, на взаємодію користувачів з інструментами децентралізованих фінансів. У роботі розглянуто ключових представників децентралізованих фінансів, їхню капіталізацію, доступний капітал і технологічні напрацювання. Обґрунтовано переваги та ризики використання інструментів децентралізованих фінансів, досліджено відмінності між централізованими, децентралізованими та алгоритмічними стейблкоїнами. Для оцінки капіталізації інструментів децентралізованого фінансування використано показник вартості активів TVL (Total Value Locked). TVL відображає суму активів, які наразі розміщені в конкретному децентралізованому фінансовому інструменті або протоколі. Наратив RWA є важливим у криптопросторі, оскільки він демонструє зростаючу взаємозалежність. DeFi, раніше ізольований від TradFi, тепер став невід'ємною частиною більш цілісної фінансової екосистеми. Технологія блокчейн продемонструвала свій потенціал для трансформації через реальні приклади використання. Реальні активи (RWA) є привабливим варіантом через великий традиційний фінансовий ринок. Хоча вони пропонують такі переваги, як диверсифікація портфеля та підвищена прибутковість, вкрай важливо зменшити ризик дефолту. Такі платформи, як Goldfinch, мають перевірену репутацію. Токенізація RWA може збільшити участь у ринку та фінансову інклюзивність. Результати дослідження свідчать про значний розвиток інструментів децентралізованого фінансування протягом останніх трьох років. Про це свідчить обсяг капіталу, інвестованого в ці інструменти, та кількість користувачів, незважаючи на технологічні та регуляторні ризики, пов'язані з ними. Висновки дослідження свідчать, що, незважаючи на технологічну новизну, користувачі все більше зацікавлені у взаємодії з інструментами децентралізованих фінансів. Однак вони стикаються з труднощами в розумінні того, як ці інструменти працюють, і в отриманні досвіду роботи з цими продуктами. Порівняльний аналіз Саїфа Ахмеда Абдулхакіма та Цюлін Ху під назвою «CeFi vs. DeFi – порівняння централізованих і децентралізованих фінансів» систематично протиставляє централізовані фінанси (CeFi) децентралізованим фінансам (DeFi) у правовому, економічному, безпековому аспектах, а також в аспекті конфіденційності та маніпулюванні ринком. Він має на меті забезпечити структурований підхід для розрізнення послуг CeFi і DeFi, підкреслюючи переваги DeFi у прозорості та контролі з боку користувача. Проте невирішені питання децентралізованих фінансів, такі як нормативно-правова база та оцінка ризиків, потребують подальшого дослідження. Дослідження також підкреслює важливість поліпшення якості користувацького досвіду та подолання викликів, пов'язаних з упровадженням DeFi. У своїй науковій статті «Завдяки технології блокчейн: DeFi (децентралізовані фінанси) прагнуть підвищити фінансову доступність для людей, які не мають банківських рахунків, шляхом реформування світової фінансової системи» Абдулхакім і Ху аналізують потенціал DeFi у підвищенні фінансової доступності для людей, які не мають банківських рахунків. Вони підкреслюють ключову роль блокчейну, зокрема Ethereum, у забезпеченні DeFi. Визнаючи переваги децентралізації DeFi, автори статті пропонують розглядати її як доповнення, а не заміну традиційним фінансам. Стаття закликає до подальших досліджень щодо інтеграції DeFi-технології з глобальними банківськими системами та поліпшення користувацького інтерфейсу і безпеки. Загалом, визнаючи трансформаційний потенціал DeFi-технологій, автори статті підкреслюють необхідність подальших досліджень для вирішення проблем і безперешкодної інтеграції DeFi-технологій у традиційні фінансові.

Ключові слова: *децентралізовані фінанси, централізовані біржі, децентралізовані біржі, стейблкоїн, смарт-контракт, блокчейн, реальні активи.*
Табл.: *3.* ***Бібл.:*** *44.*

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Decentralized finance or DeFi is a new trend that is emerging in the financial infrastructure. The use of secure distributed ledgers by cryptocurrencies is the basis of decentralized finance technology.

DeFi is becoming one of the main structural elements that have been missing in the crypto and blockchain world, which aims to become an alternative to traditional financial instruments through openness and cross-border access at any time to financial markets conducted on public blockchains. The total amount of pledged assets for all decentralized financial products, in traditional finance analogous to the portfolio of assets across the entire banking sector, in December 2019 ranged from USD 400 million to USD 600 million, and in 2021 the maximum value was from USD 217 billion to USD 244 billion, which indicates the potential and prospects for the development of this sector.

After the bankruptcy of one of the leading cryptocurrency exchanges FTX (Future Exchange) and other centralized institutions that provided services and stored cryptocurrency assets on their platforms in 2022, the issue of decentralization has become even more relevant, so it is necessary to analyze and identify the differences between centralized and decentralized cryptocurrency exchanges.

The article *aims* to substantiate and disclose the essence of decentralized finance, identify its inherent advantages and risks, and analyze the current state and development prospects.

Unlike traditional finance, which is characterized by a centralized system and can limit control over assets, DeFi is built on blockchain, the technology that is established out of control on the part of a central authority or intermediaries. Due to the absence of a third party, transactions are carried out directly between two parties and access to financial instruments is open to a large number of people. The services provided by centralized institutions and

traditional banks at different stages of their development are available in DeFi, taking the advantages of financial transactions such as speed, efficiency and cheapness, and moreover, unlike common bank transfers, these transactions can be carried out around the clock. The assets used in DeFi products remain under the control of the user (non-custodial).

Smart contracts are used to achieve distributed consumption in DeFi systems, which were first built on the Ethereum blockchain but are now available on other blockchains, too. The difference and peculiarity of a smart contract over a regular contract are that smart contracts are written not by lawyers, but by developers, who perform actions only if certain conditions are met, and if the conditions prescribed by developers in smart contracts either are not met or are met partly, the contract is not fulfilled. Anyone will be able to read the code and gain access when the smart contract is transferred to the blockchain, but no one will be able to tamper with or replace it. Financial programs or applications managed by smart contracts are called decentralized programs or "dapps" [1].

The article titled "CeFi vs. DeFi – Comparing Centralized to Decentralized Finance" by Qin et al. compares Centralized Finance (CeFi) and Decentralized Finance (DeFi) across various dimensions, including legal, economic, security, privacy, and market manipulations. The article aims to provide a structured methodology for distinguishing between CeFi and DeFi services and exploring potential synergies between them [2]. The study emphasizes the advantages of DeFi over CeFi in terms of transparency and control. In the DeFi ecosystem, users can scrutinize precise regulations and retain control over their assets. Furthermore, DeFi offers enhanced accessibility and potential for higher returns, which attracts users seeking augmented yields on investments. However, there are still unresolved aspects within decentralized finance that require further inquiry. This includes the need for a comprehensive exploration of regulatory frameworks governing CeFi and DeFi. The study also calls for the development of robust risk assessment frameworks tailored to the decentralized finance domain. Additionally, it emphasizes the importance of addressing user experience design and adoption challenges to foster widespread acceptance of decentralized financial products. In conclusion, the paper provides valuable insights into the contrast between CeFi and DeFi. However, further research is needed to address unresolved issues and advance understanding of decentralized finance for its integration into mainstream financial discourse.

The academic article, "Powered by Blockchain Technology, DeFi (Decentralized Finance) Strives to Increase Financial Inclusion of the Unbanked by Reshaping the World Financial System" by Saif Ahmed Abdulhakeem and Qiuling Hu, presents a comprehensive analysis of Decentralized Finance (DeFi) and its potential to revolutionize global finance. The article particularly focuses on how DeFi can enhance financial inclusion for the unbanked population [3]. The paper discusses the limitations of traditional financial systems and highlights the pivotal role of blockchain technology, specifically Ethereum, in enabling the emergence of DeFi. The study emphasizes the decentralization of DeFi, which eliminates the need for central authorities. However, it does not extensively explore associated risks such as smart contract vulnerabilities. The article discusses the potential of DeFi to offer banking services to those without access to traditional banking. It acknowledges the challenges of accessibility, user interface, and security. The article suggests that DeFi can complement traditional systems rather than replace them entirely. Future research should explore integration with global banking systems and digitalization within financial institutions. In conclusion, the article provides valuable insights into DeFi's transformative potential. However, it also highlights persistent challenges and areas for further research, such as risk mitigation, user interface enhancement, and seamless integration with traditional finance.

CEX (Centralized crypto exchanges) are similar to stock exchanges. The similarity for users is manifested in the type of trading platform or terminal where cryptocurrency assets are traded. A characteristic feature of centralized exchanges is that they operate at the expense of a centralized authority, and trading is carried out through an order book (order) that stores data on the placement of orders by traders to buy or sell cryptocurrencies.

The main representatives are Binance and Coinbase. DEX (Decentralized cryptocurrency exchanges) are a type of crypto trading platform that allows trading in cryptocurrencies but operates without the participation of a third party. Dependence on centralized authority on decentralized exchanges is eliminated due to smart contracts built on the blockchain and functioning to execute transactions [4]. Among the most popular representatives of decentralized exchanges are Uniswap and dYdX.

As can be seen from *Tbl. 1*, the differences between CEX and DEX are significant, but both centralized and decentralized exchanges have certain advantages and problems. The bankruptcy of the centralized exchange FTX has significantly affected the confidence of cryptocurrency market participants in CEX. Traders and investors are increasingly paying attention to and using decentralized services. The

Table 1

The main differences between centralized (CEX) and decentralized (DEX) cryptocurrency exchanges

Type of exchange and representatives	Liquidity	Regulation (anonymity)	Trading options	Security (storage)	User experience and interaction
CEX: Coinbase Binance	Currently, centralized exchanges outperform DEX with more users and higher liquidity	Subject to rules that may vary significantly from one jurisdiction to another, but must comply with Know Your Customer (KYC) and Anti-Money Laundering (AML) standards. Currently subject to little regulatory scrutiny. Users must provide detailed personal information such as name, social security number or passport, address, etc.	They allow users to take advantage of borrowing, futures trading, options, spot trading, leverage, etc.	Centralized exchanges facilitate cryptocurrency trading through sophisticated and centralized platforms. The storage of the assets is custodial and therefore the user must trust the exchange with their assets and in case of problems with the exchange, access to the assets will be blocked	Centralized exchanges are often expensive, making such exchanges less accessible to everyone. They provide investors and traders with a convenient solution for cryptocurrency trading that is easy to understand even for beginners
DEX: dYdX Uniswap	One of the problems is low liquidity, which makes it difficult to attract large traders to these platforms	DEXes are currently much more lenient in this regard, allowing decentralized exchanges to offer traders anonymity. On decentralized exchanges, sensitive data is not required to complete an exchange	DEX is still in its infancy, but options are one of several rapidly evolving components of the DeFi ecosystem	They work through smart contracts that are based on the code. However, the open-source nature of DEX means that anyone can review the code, find weaknesses, and take advantage by manipulating the system. Users retain full control over their assets throughout the transaction process thanks to smart contracts	DEX, on the other hand, stand out for its low transaction fees due to its reliance on self-executing code-based algorithms, but these are still in their infancy and have additional layers of complexity

Source: compiled by the author based on data from [4].

growing popularity of cryptocurrency trading suggests that innovation and progress will be the driving force in this direction. A characteristic feature of blockchain technology is decentralization, so this is the key element in the comparison of CEX and DEX.

As mentioned above, the first applications began to be built on the Ethereum blockchain, and the vast majority of users still prefer decentralized applications built on Ethereum, the reason being the highest liquidity and trust of participants.

The role of banks in terms of traditional finance in decentralized finance is played by financial liquidity protocols, which allow users to both deposit and borrow money. Among the main protocols involved in this activity are Aave and Compound.

Aave is a decentralized liquidity protocol. Depositors provide liquidity to the market and receive passive income, while creditors can get a loan under collateral, which must be highly secured [5]. Assets in this case can be cryptocurrencies or stablecoins, the main task of which is to maintain parity with the USD, the so-called crypto dollar. Interest rates depend on the collateral, namely the cryptocurrency that is deposited or the collateral that is provided as a loan se-

curity. As in traditional finance, the collateral is valued at market value.

Compound Finance is a digital crypto marketplace that offers the lending and borrowing of digital assets. Technically, like Aave, Compound finance is built on the Ethereum blockchain through smart contracts that allow the building of decentralized applications [6].

Aave and Compound Finance are very similar in their operation, but Aave has technological advantages that Compound does not have, such as fast loans and support for multiple blockchains. This gives them an advantage in terms of attracting traders for arbitrage and regular users who want to avoid high transaction fees on the main Ethereum network [7].

In DeFi, the TVL (total value locked) indicator is used to compare the number of locked assets that are on a particular protocol. TVL is the total value of locked assets. According to Defilama, which analyzes TVL indicators, in 2020, on December 25, TVL Aave was USD 2.07 billion, a year later the value was USD 27.65 billion, on December 25, 2020, the value was USD 5.83 billion [8]. In Compound finance in 2020, on December 25, TVL was USD 1.95 billion, a year later the value was USD 17.21 billion, and now it amounts to USD 2.35 billion [9]. As can be seen from the above data, the growth dynamics of Aave and Compound Finance are similar, but Aave has a higher value and one of the main factors of influence is the connection of additional blockchains to interact with the protocol. Compared to the previous year, there is a decrease in the TVL indicator and the main factors of influence were the fall in the total capitalization of the cryptocurrency market by 2.97 times according to the Coingeco website, the collapse of the cryptocurrency Luna on the blockchain of which DeFi protocols were built and stablecoin UST, which lost its 1 to 1 parity with the USD, as well as the bankruptcy of one of the world's major crypto exchanges FTX, which affected investors' confidence in the cryptocurrency market in general [10].

As mentioned above, in DeFi, DEXs are replacing centralized cryptocurrency exchanges. A decentralized exchange or DEX is a marketplace similar to a stock market where users or traders can exchange cryptocurrencies with each other, thus avoiding a centralized service. DEX is distinguished by the fact that cryptocurrency exchange is ensured through the use of smart contracts, which include self-executing agreements defined in the code. One of the main tasks in creating DEX was to eliminate the need for any authority to supervise and authorize transactions on the exchange [11].

One of the main advantages of DEX is the elimination of the need for any authority to supervise and authorize transactions on the exchange, as noted above, the exchange takes place through a smart contract on a specific blockchain [11]. The disadvantage of DEX is the speed of transaction settlement and liquidity that centralized exchanges have, but the assets are kept by users and thus avoiding the trust in a centralized exchange. Most blockchains have their DEX built on them, but the main and most famous DEX is Uniswap, which is built on Ethereum.

Uniswap is the main decentralized exchange protocol, which was first launched on the Ethereum blockchain, that can perform the so-called "Peer-to-Peer" cryptocurrency transactions. Centralized crypto exchanges follow the order book model for trading and thus keep open orders to buy or sell an asset that is present on the exchange. With this model, there is a decrease in liquidity and trading activity if there is a gap between the prices of buyer and seller orders. The peculiarity of Uniswap and decentralized exchanges is that there is no need for a centralized intermediary or order book as on centralized platforms. On the contrary, Uniswap DEX uses a liquidity pool model with automated smart contracts [12]. Decentralized exchanges, such as Uniswap, use a smart contract with blockchain tokens to trade between assets, which is called a liquidity pool [13].

Uniswap, through liquidity pools, eliminates the discrepancy between buyer and seller prices and helps to support liquidity problems. The main technology that achieves the above is the Automated Market Maker (AMM) technology. AMM is a smart contract built on a blockchain, as noted, first of all on Ethereum, which manages liquidity pools and thus facilitates token trading. It is worth noting that AMM achieves the so-called "effective" price between the supply and demand of a token.

Uniswap distinguishes three types of users present on the exchange, namely [14]:

- Users who provide crypto assets (tokens) to assist in trading, the so-called liquidity providers;
- Users or traders who exchange tokens for each other;
- Developers, doing their work.

These three types of users are a vital element and driver of development for the functioning of decentralized exchanges that operate in a technologically similar way to Uniswap. If Uniswap is an exchanger, then dYdX is a trading platform where cryptocurrencies are traded.

dYdX is one of the leading decentralized exchanges specializing in derivatives trading and spot market trading in cryptocurrencies. Trading is supported by an asset order book, a chart with indicators, and selected market positions that can be spot or leveraged

[15]. A characteristic feature of traditional futures contracts is that each order has a certain time limit, after which it is automatically canceled, while dYdX and decentralized exchanges offer users perpetual futures contracts. Perpetual contracts allow traders or investors to place buy or sell orders for an indefinite period, unlike spot trading, which is based on the market price when selling or buying cryptocurrency instantly [16]. An example of how perpetual contracts work can be explained by the example of a user who has placed a sell order for USD 10.000 for 1 Ethereum and the order will wait for this price condition to be met, but the user has the option to close the order before this condition, thus terminating the contract.

The difference between Uniswap and dYdX is that Uniswap is primarily an exchanger, while dYdX is a trading platform where cryptocurrencies are traded.

The bankruptcy of the cryptocurrency exchange FTX and one of the main lending platforms Celsius, which took place in November and July 2022, respectively, led to the cascading bankruptcy of some other centralized platforms that provided services to users for interaction with the cryptocurrency market. FTX users are unable to withdraw their assets and potentially in the future, possible withdrawals will be made at a lower asset price, for example, with assets worth of USD 100, the user will receive the worth of USD 25, it should also be noted that the bankruptcy procedure is not fast, so users may not be granted access to their assets.

Currently, Uniswap, which is the largest decentralized exchange in the DeFi sector, surpassed one of the main centralized cryptocurrency exchanges Coinbase on November 15, 2022, in terms of daily trading volume on Ethereum pairs. According to the research company Delphi Digital, in mid-November, centralized exchanges experienced a net outflow of USD 5.5 billion from exchanges to Ethereum within 7 days and an increase in the basket of assets of decentralized exchanges by 33.8% compared to BTC [17]. In November, trading volumes on decentralized exchanges increased by almost 11% to USD 62 billion, according to CryptoCompare data obtained from DefiLlama. During the period of FTX's fall in November, Nansen data shows that the growth in the number of users on decentralized exchanges dYdX and Curve Finance reached 97% and 61%, respectively, with the number of transactions more than doubled. The number of users of lending protocols such as Aave and Compound grew by 68% and 46%, and the number of transactions also doubled [18].

Centralized cryptocurrency exchanges are currently playing an important role in the cryptocurrency market by making it easier for inexperienced users to use. After events like the exchange's bankruptcy, market participants should remember that when assets are stored on centralized platforms, access to the assets depends on a third party. Drawing an analogy between a centralized exchange and a bank, during a crisis of confidence, a "panic bank run" may occur, with investors trying to quickly withdraw their assets, potentially leading to a liquidity crisis. The bankruptcies of centralized platforms have become a catalyst for attention and interaction with the DeFi sector among participants looking for a "safe haven" for their assets.

DeFi is becoming a new direction for the use of capital generated in the global financial markets. The need to understand the risks that are present in DeFi products is mandatory. To maintain collateral in such lending products as Aave and Compound, a liquidation mechanism is used to allow participation in the capital of unsecured positions. When operating decentralized exchanges like Uniswap, there is a risk of paying high fees due to slippage in price or low liquidity of a particular asset. When searching for higher margins, DeFi users encounter the internal risk of the protocol, in which the risk is transferred to the programmable mechanics of the protocol. When creating decentralized programs, smart contracts are used that are written by humans, so mistakes are inevitable. Decentralized programs are released as open source, on the one hand, participants can analyze and observe errors and, if necessary, quickly identify and correct them, on the other hand, attackers can use gaps for their purposes to steal assets. Hacking in DeFi is becoming a technological risk.

This problem is solved by auditing the code and extensive testing before the code is released to the network. The market risk is investing in liquidity pools to generate passive income, but volatility in asset prices can cause cascading liquidations of investors' positions. Compared to traditional financial instruments, the decentralized finance segment is not regulated, which means that in case of loss of an asset under various circumstances, users will not be able to appeal to the judicial authorities.

The cryptocurrency market is characterized by high volatility, cryptocurrency prices can change significantly during a day, so problems may arise for everyday payment for goods or when using collateral in DeFi. To solve this issue, a type of cryptocurrency called "stablecoin" was created. Stablecoin is a type of cryptocurrency of a certain issuer whose task is to maintain a 1:1 parity with the central bank currency, the most common and most liquid is pegged to USD. Stablecoins are a product built on many different blockchains.

There are different types of stablecoins, namely centralized, decentralized, and algorithmic.

Centralized stablecoins are those that are controlled and issued by a centralized issuer, backed by cash and highly liquid securities of the US government.

The main representatives of centralized stablecoins are Tether's USDT and Circle's USDC. These are the two largest stablecoins in the cryptocurrency market. USDC is backed by USD 31.9 billion, while USD 31.8 is issued [19]. At the same time, Tether, which is the issuer of USDT, notes that the assets are 1 to 1 secured [20]. With the movement of highly liquid assets, these two companies can provide and maintain parity with the currency of central banks. The negative aspect of centralized stablecoins is that you need to trust a third party that will do its job and maintain the peg. Circle and Tether issue independent audit reports monthly, showing the balance of assets that the companies have to back their stablecoins.

It should also be noted that if earlier potential investors or transfers in the cryptocurrency market were made through the first cryptocurrency Bitcoin, now this role is played by stablecoin, which solves the issue of volatility during transactions. Blockchain technology makes it possible to carry out cross-border transactions in seconds or minutes and with minimal fees, regardless of the amount of the transfer, which can sometimes be up to 1 US Dollar, depending on the blockchain, which is something the traditional financial system cannot boast of.

The main representative of the decentralized stablecoin is Dai. The Dai stablecoin is issued by users who deposit collateral assets in the vaults of the Maker lending protocol and thus gain access to liquidity. Maker is the first DeFi product that has been operating since 2017 and has a functionality similar to that of a traditional central bank. Collateral is usually deposited into the Maker vault in the Ethereum cryptocurrency on the blockchain of the same name, so Dai is issued as a product of loan demand during lending. It is worth noting that Maker vaults are over-collateralized, which helps to protect against price drops in the assets that are collateralized. Maker influences supply and demand by controlling interest rates, which in turn helps to regulate the amount of Dai [21].

Dai's assets are 123.8% secured, which indicates readiness for unforeseen situations in the cryptocurrency market [22]. Currently, the assets are backed by the native Ethereum blockchain coin and about half of them are the centralized USDC stablecoin of Circle, which raises questions about the Dai decentralization.

Algorithmic stablecoins are usually not backed by other assets and are not tied to any collateral. The functioning is carried out by a computer algorithm to maintain the value, control and influence the price is performed by a pre-programmed code performing specific actions. The main representative of algorithmic stablecoins is Frax.

Frax is a hybrid stablecoin backed by asset pledges and mathematical cryptographic algorithms. The collateral is partly both collateral and a stabilized algorithm. Frax works in the following way: if the Frax price exceeds 1 US Dollar, the platform reduces the margin ratio by one step, namely 0.25%, when the price is below 1 US Dollar, the margin ratio will be increased by one step. To successfully maintain the stability of the parity to the USD, Frax uses the margin ratio by dynamically adjusting the process [23]. The idea of algorithmic is interesting, as it does not require trust in a centralized issuer that has control over the stablecoin, nevertheless, in 2022, an event occurred that affected the credibility of algorithmic stablecoins. We are talking about the algorithmic stablecoin of the Luna blockchain, which lost parity with the USD, and at the time of writing is traded at 0.02 US Dollar for 1 UST stablecoin [23]. After this event, trust in algorithmic stablecoins has significantly decreased.

Table 2

The stablecoins' market situation as of March 31, 2024

No.	Name	Market capitalization, billion	Domination, %
1	USDT	104.35	72.11
2	USDC	31.8	21.97
3	DAI	5.35	3.69
4	FDUSD	2.56	1.76
5	FRAX	0.65	0.45
	All	144.7	100

Source: compiled by the author based on data from [24].

After analyzing *Tbl. 2*, we can conclude that the dominant type of stablecoin is centralized, with USDT, USDC, and FDUSD being the main representatives, which together account for more than 95% of the total market capitalization of stablecoins. Stablecoins are becoming a key element of interaction between the traditional financial system and DeFi, because, in the implementation of traditional financial activities such as lending and derivatives trading, it is extremely important to have a stable currency during the transaction. Currently, stablecoins are used for trading or lending, thus avoiding the volatility inherent in the cryptocurrency market. In the future, when governments regulate stablecoins, the share of cross-border and domestic transaction payments will increase significantly.

The term Real-World Assets (RWAs) has been introduced in the context of decentralized finance (DeFi) to refer to tokens, whether fungible or non-fungible, that are transacted on blockchain networks and

represent tangible assets. Examples of RWAs include a wide range of assets such as real estate holdings, loans, bonds, contractual agreements, guarantees, and other high-value items. The ongoing transformation in the financial sector is being driven by the gradual expansion of DeFi beyond its origins in the realm of cryptocurrencies. As the tokenization of assets becomes more prevalent, traditional capital markets are migrating onto blockchain infrastructures.

Real-World Assets (RWAs) offer DeFi investors a unique opportunity to diversify their portfolios by providing access to a multitude of the off-chain debt markets. Furthermore, RWAs allow institutions in traditional finance (TradFi) to tokenize and issue debt obligations and assets without being limited by geographical market constraints.

The increase in digital asset proliferation and the influx of new institutional participants highlight the importance of secure and reliable institutional custody solutions for digital assets in the DeFi ecosystem. Custodial services, such as Anchorage Digital and Copper, have been widely adopted in recent years, contributing to the institutionalization of DeFi. Currently, custody assurance primarily relies on the legal frameworks established during pool formation and adheres to standard Know Your Customer (KYC) and Anti-Money Laundering (AML) procedures. Future developments aim to integrate credit protocols with decentralized identifiers (DIDs), such as Kilt, to facilitate comprehensive asset verification. This proposal involves creating consortia of underwriters to act as unbiased third-party risk assessors.

In the institutional domain, one concern regarding DeFi is the lack of a standardized reputation system, similar to traditional credit ratings. Credit protocols in DeFi ecosystems require collateralization with liquid tokens to mitigate the inherent challenge of ensuring loan repayment in the event of defaults. While this collateralization approach effectively mitigates credit risk, it also limits the diversity of financial products within DeFi. In response, credit protocols use various strategies to include a reputation component in lending dynamics. Some initiatives aim to import reputational data from external networks into the blockchain, while others strive to establish endogenous reputation systems within the DeFi landscape. The integration of Real-World Assets (RWAs) into the framework of Decentralized Finance (DeFi) is a significant development in the intersection of traditional finance and decentralized finance.

The integration of Real-World Assets (RWAs) into the framework of Decentralized Finance (DeFi) has significant implications for the financial landscape. This confluence of institutional custodial advancements and evolving credit protocols represents a profound development in the intersection of traditional finance and decentralized finance. This analysis examines the advantages and disadvantages of integrating RWAs into the decentralized financial ecosystem. *Tbl. 3* presents the primary benefits and drawbacks of RWA and DeFi.

The integration of RWAs into the DeFi ecosystem represents a significant shift, presenting both opportunities and challenges. As the sector continues to develop, it will be crucial to address operational, legal, and technical complexities in order to fully realize the potential of RWAs in the decentralized financial landscape. Ongoing research and development are imperative to ensure the sustained evolution of the relationship between RWAs and DeFi, which is a dynamic one. This will help to maintain the innovative nature of this financial frontier.

In the rapidly changing world of decentralized finance (DeFi), Centrifuge, Maple Finance, Goldfinch, and Ondo Finance have emerged as pioneers. They are integrating traditional financial instruments and real-world assets into blockchain ecosystems. Each protocol presents a unique approach to bridging the gap between traditional and decentralized finance. They offer innovative solutions for collateralization, lending, and credit assessment. This article delves into a comprehensive exploration of these protocols, dissecting their structures, mechanisms, and contributions to the burgeoning field of decentralized finance.

Centrifuge is a decentralized finance (DeFi) protocol that specializes in structured credit. This practice is commonly seen in traditional finance (TradFi), where similar debt obligations are securitized, pooled, and their resulting cash flows are sold off. In DeFi, Centrifuge mirrors this process by using the resultant securities as collateral to enable borrowers to acquire crypto-denominated debt. The protocol has been instrumental in establishing debt pools collateralized by various structured credit assets, such as pooled mortgages, invoices, microlending, and consumer finance [26]. Centrifuge consolidates its diverse debt offerings into a decentralized marketplace known as Tinlake, providing a turnkey solution for the tokenization of structured credit and loan origination. Notably, Centrifuge was among the first protocols to organically integrate tranching into its contracts. Tranching is a feature commonly used in traditional finance (TradFi) that enables investors to access different risk exposures and yields within the same asset class. In the event of a default, payment is prioritized for more senior tranches, which hold less risk but yield less compared to junior tranches. Centrifuge offers two distinct tranches for debt offerings: senior exposure represented by a to-

Table 3

Advantages and Disadvantages of Real-World Assets (RWAs) within the Decentralized Finance (DeFi) Paradigm

Advantages	Disadvantages
1. Diversification of Asset Classes: RWAs introduce a diversified spectrum of traditional assets, including real estate, bonds, and carbon credits, thereby broadening the range of assets available within the DeFi landscape. This diversification contributes to a more comprehensive and inclusive financial ecosystem	*1. Operational and Legal Complexity:* Integrating RWAs into DeFi introduces operational and legal intricacies, necessitating seamless coordination between traditional legal frameworks and the decentralized protocols. Achieving this coordination poses challenges, requiring robust legal structures and operational frameworks
2. Tokenization and Liquidity Enhancement: Tokenization of RWAs facilitates fractional ownership and enables these traditionally illiquid assets to become more liquid in the decentralized marketplace. This liquidity enhancement allows for efficient trading and investment strategies, providing DeFi participants with increased flexibility	*2. Default and Counterparty Risks:* Despite efforts to mitigate risks, the potential for default remains a concern in RWA-backed lending. Counterparty risks arise, particularly in scenarios where traditional financial entities interact with DeFi protocols. Vigilant risk management strategies are imperative to address these concerns effectively
3. Integration of Real-World Value: RWAs bridge the gap between the digital and physical realms by anchoring DeFi protocols to tangible real-world assets. This integration enhances the credibility and stability of the DeFi space, attracting users seeking a connection to tangible, real-world value	*3. Regulatory Uncertainty:* The regulatory landscape surrounding RWAs in DeFi is evolving and subject to uncertainty. Navigating regulatory frameworks presents a challenge, requiring adherence to existing financial regulations while operating within the decentralized and often cross-border nature of DeFi
4. Risk Mitigation and Stability: The inclusion of RWAs introduces a layer of stability to the typically volatile DeFi ecosystem. Assets such as bonds and real estate, known for their relative stability, provide avenues for risk mitigation, attracting risk-averse investors seeking more reliable returns	*4. Scalability and Technical Challenges:* As the volume of RWAs integrated into DeFi grows, scalability issues may emerge. Technical challenges, such as the efficient on-chain representation of diverse real-world assets, require continuous innovation to ensure the seamless functioning of DeFi platforms

Source: compiled by author based on data from [26].

ken called DROP and junior exposure represented by a token called TIN. The protocol stands out in the RWA space due to its wide network of partnerships with both crypto and traditional finance entities. On the crypto side, Centrifuge has integrated with MakerDAO and Aave, providing access to their liquidity pools. Furthermore, Centrifuge RWA pools currently support the DAI stablecoin and are considering supporting Aave's GHO stablecoin in the future.

In the TradFi domain, Centrifuge has attracted several prominent financial institutions seeking to issue debt. Notably, in December 2022, it announced a USD 220 million fund with MakerDAO and BlockTower Credit, marking the largest on-chain investment in RWAs to date. This collaboration represents the first institutional credit fund to bring collateralized lending operations onto the blockchain [27].

Centrifuge introduces mechanisms to incorporate Non-Fungible Tokens (NFTs) into the on-chain credit ecosystem, allowing for the inclusion of various forms of real-world assets. The parties involved in this process are Asset Originators (borrowers) and Investors (lenders). The decentralized application (dApp) Tinlake acts as a marketplace and investment dApp, facilitating lending by tokenizing real-world assets into NFTs, creating asset pools, and issuing DROP and TIN tokens. DROP token holders receive a fixed interest per pool, while TIN token holders earn variable yields based on investment returns from the pool, assuming a higher risk. In the event of borrower default, TIN token holders bear the initial loss. This approach has enriched the landscape of on-chain credit, positioning Centrifuge as a pioneering force in decentralized finance [28].

Maple is an uncollateralized borrowing and lending protocol that uses "pool delegates" to evaluate creditworthiness, define loan terms, and oversee loan portfolios. Liquidity providers (LPs) commit capital to restricted liquidity pools and earn MPL interest in return. Maple initially focused on uncollateralized lending to crypto-native entities but has since expanded to include loans associated with Real World Assets (RWA). However, the protocol faced challenges when it concentrated on uncollateralized crypto lending to crypto trading firms, resulting in Maple encountering bad debt of USD 52 million and up to 80% losses for certain Maple LPs. These setbacks occurred following a centralized contagion last year that affected Maple's crypto-native borrowers. Maple's

pool delegates are exploring opportunities to originate loans secured by real-world asset collateral, diverging from conventional crypto collateral. In January, Maple established a USD 100 million liquidity pool backed by tax receivables [16]. Maple Finance is an institutional capital market infrastructure that provides a platform for institutional borrowers to access loans within the decentralized finance (DeFi) ecosystem [28].

The lending process on Maple Finance involves three principal parties: Institutional Borrowers, Lenders, and Pool Delegates. The Maple Finance platform has three types of participants: Institutional Borrowers are those seeking loans within the platform, while Lenders are DeFi participants who deposit capital into Maple Finance pools. Pool Delegates are credit professionals who are responsible for underwriting and managing the pools on Maple Finance.

The lending process on Maple Finance occurs in the following manner [28]:

1. Pool delegates actively search for institutional borrowers, conducting thorough due diligence, underwriting, and negotiating terms, while adhering to Know Your Customer (KYC) and Anti-Money Laundering (AML) processes.
2. Once the suitability of institutional borrowers for borrowing has been verified, pool delegates establish and manage the pools on Maple Finance.
3. Lenders use the Maple Finance platform to find pools that match their risk appetite and preferred terms.
4. Institutional borrowers gain access to the capital by depositing it into the pool. The whitelisting process conducted by pool delegates enables undercollateralized borrowing.

Goldfinch operates as a protocol that enables businesses, particularly those based in emerging markets, to access crypto lending without providing crypto collateral. Instead, the loans are collateralized with Real World Assets (RWAs), making it possible for virtually any business to secure crypto loans. This innovative approach is particularly beneficial for businesses operating in emerging markets that lack robust financial infrastructure or are grappling with currency devaluation concerns. Goldfinch has successfully originated over USD 120 million in RWA-based loans for emerging market businesses [28]. The protocol employs a unique vetting mechanism for businesses seeking borrower status on its platform. On the Goldfinch platform, users known as "auditors" stake the Goldfinch native token, GFI. This empowers them to cast votes on whether a borrower should access a credit line on Goldfinch. Auditors are instructed to base their votes solely on their assessment of a borrower's creditworthiness. Aligning with the consensus during voting earns auditors GFI tokens as a reward. After a borrower is validated by auditors for credit extension, the proposed deal terms for credit lines are structured into a decentralized finance (DeFi) borrowing/lending pool. Subsequently, investors can opt for capital allocation. Goldfinch debt offerings feature a seniority structure similar to Centrifuge. Investors may allocate capital to individual pools, becoming "backers" investing in a more risk-exposed, first-loss junior tranche. Alternatively, investors can distribute their liquidity throughout the entire protocol, diversifying their funds and holding a senior position relative to the first-loss capital of backers. It is worth noting that Goldfinch's loan book has not experienced any defaults or bad debt so far [30].

The Goldfinch protocol generates revenue through withdrawal fees from investors and backers, as well as a 10% share of interest payments directed to protocol reserves [17]. Since its inception, the protocol has accumulated over USD 1.6 million in revenue [18]. Goldfinch's business model is resilient, demonstrating the ability to operate independently of crypto market fluctuations [30].

The lending process on Goldfinch involves three key parties:

1. *Borrowers:* Initiators proposing Borrower Pools to secure capital financing through Goldfinch.
2. *Investors:* Capital providers to borrowers, with two distinct types – Backers and Liquidity Providers.
3. *Auditors:* Participants conducting due diligence to ensure the absence of fraudulent activities among borrowers on the Goldfinch platform.

The lending process unfolds as follows:

1. Audit and Eligibility: Borrowers undergo an audit by auditors to establish their eligibility for loans.
2. *Borrower Pool Creation:* Approved borrowers create borrow pools, stipulating credit terms such as interest rate, limit, payment frequency, term, and late fees.
3. *Capital Supply:* Investors enter the picture to supply capital.
4. *Backer Capital:* Backers supply capital directly to borrower pools, assuming the first-loss position and receiving a higher return.
5. *Liquidity Providers:* Capital from liquidity providers is allocated across all borrower pools [28].

Ondo Finance has introduced institutional-grade financial products, including government bonds and high-yield bonds, into the decentralized finance (DeFi)

landscape. This strategic move is achieved through the establishment of three distinct investment funds: OUSG (Short-term US Government Bond Fund), OSTB (Short-term Investment Grade Bond Fund), and OHYG (High-Yield Corporate Bond Fund), each holding ownership of the underlying institutional assets. The distinctive aspect of these investment funds is their tokenization into Real World Assets (RWAs), which are referred to as "fund tokens". Users can trade these fund tokens within permissioned DeFi protocols after completing a Know Your Customer (KYC) and Anti-Money Laundering (AML) process. It is worth noting that the Ondo Protocol, in partnership with Bondblox, is one of the few protocols actively contributing to the development of the public credit RWA market. This initiative enables blockchain users with significant on-chain capital to keep their assets on-chain and earn returns outside the crypto sphere through relatively secure fixed-income products. The demand for this service has increased due to the need for on-chain cash management, particularly as real DeFi yields decline while interest rates in public credit markets rise [26].

Ondo Finance has achieved significant and consistent growth, as demonstrated by the increase in its Total Value Locked (TVL), which currently stands at approximately USD 163.35 million. It is worth noting that it holds the position of the second-largest RWA protocol, only being second to stUSDT [28]. The strategic allocation of funds into multi-billion dollar, highly liquid exchange-traded funds enables stablecoin holders to earn yield on their assets. This mechanism involves exchanging users' stablecoins for USD, which are then used to purchase assets. New fund tokens, representing these investments, are created and deposited into users' wallets. As these assets generate yield, the resulting returns are reinvested. Upon redemption, the corresponding fund tokens are burned, and users receive USDC in return. Ondo Finance offers Annual Percentage Yields (APY) ranging from 4.5% to 7.76%, depending on the risk profile.

In a recent development, Ondo Finance has introduced Ondo USD Yield (USDY), which is a tokenized note overcollateralized by short-term US Treasuries and bank demand deposits. USDY represents a pioneering effort by Ondo Finance to grant investors access to yield within an institutional-grade framework, ensuring an elevated level of security in the investment structure.

In conclusion, Centrifuge, Maple Finance, Goldfinch, and Ondo Finance are notable examples of how decentralized finance is reshaping the landscape of traditional finance. These protocols offer innovative solutions for collateralization, lending, and investment in the digital era. Their distinctive features and approaches demonstrate the potential for decentralized systems to integrate real-world assets and traditional financial instruments seamlessly. As the decentralized finance ecosystem matures, these protocols are leading the way in combining blockchain technology and traditional finance. They are paving the way for the convergence of these two financial paradigms and fostering a more inclusive, efficient, and interconnected financial landscape.

Smart contract platforms have a significant impact on the overall cryptocurrency market capitalization. In recent years, there has been a noticeable increase in the number of smart contract platforms, each with unique features and limitations. This trend is a distinct phenomenon where one blockchain aims to address the shortcomings of another while still having its own inherent limitations. The advancements in this domain primarily focus on rectifying limitations and fostering seamless communication channels between platforms and decentralized applications (DApps) built on them.

The goal of cross-chain technologies is to construct frameworks that facilitate the exchange of information across different blockchains. One of the most important technologies in the blockchain space is cross-chain bridges, which are widely recognized for their pivotal role. These bridges enable the migration of cryptocurrencies, non-fungible tokens (NFTs), and other data from one blockchain to another.

Although cross-chain bridges offer a transparent service by allowing the actual relocation of tokens between blockchains, they do not conclusively resolve the overarching interoperability conundrum. In addition, this approach presents a range of security vulnerabilities and user experience challenges. According to a recent report by Chainalysis, cross-chain bridges have been responsible for losses exceeding USD 2 billion in the first three quarters of 2022. The complexities of bridging technologies expose vulnerabilities, making them susceptible to exploitation [32].

In addition to security concerns, it is important to recognize that cross-chain bridges are still in their early stages of development and are primarily limited to asset bridging. This falls significantly short of establishing genuine "communication" channels between blockchains. True interoperability goes beyond the mere exchange of ledger-recorded information and envisions a scenario where one blockchain seamlessly leverages the functionalities of another.

Cross-chain messaging is a crucial aspect of interoperability, serving as a foundational link that guides developers in creating composable applications. Unlike previous bridge iterations that focused

mainly on token transfers, modern cross-chain messaging protocols have surpassed these limitations by enabling the transmission of arbitrary data across different networks. Consequently, it facilitates cross-chain execution and enables new use cases.

When examining the mechanics and frameworks of each protocol, it is important to note that cross-chain messaging protocols serve as connectors for blockchains. They go beyond the traditional conception of bridges and act as the underlying infrastructure that allows a variety of applications to operate smoothly on top of them. These protocols support various cross-chain operations, including governance, lending, yield farming, and NFT exchanges. Technical term abbreviations are explained when first used, and the text adheres to conventional academic structure and formatting. The text is free from grammatical errors, spelling mistakes, and punctuation errors. Their significance lies not only in token transfer but also in the seamless transmission of arbitrary data and programmable transactions. The language used in the text is clear, objective, and value-neutral, and the sentences are concise and logically structured. No changes in content have been made as per the instructions. To fully understand these protocols, it is necessary to analyze both their messaging process and implementation. The process of messaging involves examining the specifications that govern the transmission of messages, whether they are tokens or data, from the source blockchain to the target blockchain. This requires a detailed analysis of the protocol's infrastructure design, security measures, and unique components. At the same time, the implementation aspect involves exploring the applications and use cases built on top of these messaging protocols. To demonstrate their capabilities and differences, this text highlights two representative implementations for each protocol, providing insight into the nuanced landscape of cross-chain messaging [33].

The Chainlink Cross-Chain Interoperability Protocol (CCIP) was introduced during its Early Access phase in July 2023. It aims to establish a global liquidity network that interconnects diverse blockchains, ranging from public chains to private banking chains. The protocol is Chainlink's solution for cross-chain interoperability. The foundation of CCIP is formed by Chainlink Decentralized Oracle Networks (DONs), which are intricate networks of oracle nodes that execute on- and off-chain computations, thereby expanding the functionalities of smart contracts. CCIP efficiently facilitates three distinct categories of cross-chain messaging: data transmission, token exchange, or a combination of both. This is an unparalleled achievement within the space, as CCIP attains a level-5 interoperability standard, as per Chainlink's documentation [34].

CCIP's distinctive prowess is evident in its sophisticated security architecture. This uniqueness is encapsulated in three independent networks: the Risk Management Network, the Committing DON, and the Execution DON. Each network incorporates multiple independent nodes, which are operated independently with unique keys, thereby fortifying decentralization at its core. The software code divergence between the Risk Management Network and the other two networks highlights CCIP's commitment to robust security practices [35]. This design choice demonstrates CCIP's dedication to prioritizing security in its operational paradigm. The use of three distinct networks for transaction verification improves the robustness of the verification process and reduces the risk of network overload. This enhances reliability and addresses common performance challenges associated with protocols that use a single, monolithic network system [36].

In collaboration with Chainlink Labs, the Australia and New Zealand Banking Group Limited (ANZ), a prominent institutional bank in Oceania, explored the feasibility of a cross-chain settlement solution leveraging CCIP. The focus of this collaboration was to validate on-chain Delivery versus Payment (DvP), a settlement methodology that ensures simultaneous or post-payment exchange of securities. The trial was executed in a test environment using CCIP as the backend infrastructure. It yielded a noteworthy outcome by successfully showcasing the capability for a customer to use an ANZ-issued New Zealand dollar stablecoin to purchase tokenized Australian asset NFTs, which were valued in a different stablecoin on another blockchain [37]. CCIP played a crucial role in ensuring that both the buyer and seller received their payment and NFTs simultaneously in a single blockchain transaction, achieving atomic cross-chain settlement. Ultimately, CCIP serves as a facilitator for the transfer of value from banks to public chains, streamlining the integration process with Traditional Finance (TradFi). Enabling the connection of existing systems to CCIP allows organizations to utilize their familiar APIs and messaging services to set goals and execute on-chain transactions. CCIP serves as a unified integration point, providing access to multiple blockchains and DeFi-based decentralized applications (dApps), empowering protocols and institutions to access an expanded pool of liquidity and users. CCIP is expected to play a crucial role in connecting traditional finance with various blockchain networks, making it an essential component of the changing financial landscape.

Axelar is a Proof-of-Stake (PoS) network constructed using the Cosmos SDK. Its purpose is to func-

tion as a communication layer that facilitates dApp interaction across the Ethereum Virtual Machine (EVM) and Cosmos ecosystems. Axelar enables the seamless transfer of tokens, execution of smart contract calls, and transmission of general messaging, all of which are orchestrated by a network of validators. Validators play a crucial role in maintaining the integrity of the system by overseeing the network's state, transaction authentication, and cross-chain communication. Axelar incorporates security-enhancing mechanisms such as quadratic voting and key rotation [38]. Unlike conventional PoS systems, where stake concentration can lead to power centralization through weight delegation, quadratic voting acts as a natural deterrent to voting power concentration, promoting greater decentralization. Validators also enhance security by periodically rotating their key shares, adding an extra layer of protection against potential vulnerabilities. Axelar Gateways complement these security measures by implementing rate limiting, which curtails the volume of assets transferable within specific intervals. These measures collectively contribute to maintaining the operational integrity and safety of the network.

Since 2023, Axelar has experienced a significant increase in adoption, as evidenced by the rise in transaction numbers and active user participation. This surge is mainly attributed to the implementation of the General Message Passing (GMP) feature, which enables sophisticated cross-chain function calls and state synchronization. In May [39], GMP expanded its support to facilitate interactions between Cosmos and EVM chains, signifying a substantial advancement for Axelar. Prior to GMP, interoperability between these ecosystems was limited predominantly to asset bridging, which limited composability. GMP's introduction brought about intricate interchain communication, underscoring its significant role in driving Axelar's heightened usage. The impact of GMP can be quantified by the 2023 data, which indicates that approximately 72% of transactions involve GMP messaging, and roughly 93% of active users engage with GMP [40]. This underscores its pivotal role in Axelar's growth trajectory.

A noteworthy illustration of GMP's utility is exemplified in its integration with Ondo Finance, a leading issuer of on-chain U.S. T-Bills. Axelar leverages GMP for the Ondo bridge, facilitating a unified on-chain USDY liquidity. Furthermore, Axelar has established important enterprise partnerships, as demonstrated by its recent collaboration with Microsoft, which marks Axelar's entry into the Azure Marketplace [41]. This strategic alliance extends Axelar's tools, such as AxelarJS SDK and GMP, to developers, providing advanced hybrid blockchain solutions. This collaboration has the potential to significantly catalyze Axelar's growth and expansion, given the widespread use of Azure globally.

LayerZero, created by LayerZero Labs, is an omnichain interoperability protocol designed to facilitate secure and reliable transfers across its supported networks. Its main goal is to reduce the risks associated with using centralized exchanges (CEXes) for bridging and to address the inefficiencies present in certain cross-chain methodologies that require intermediaries. LayerZero has added the Omnichain Fungible Token (OFT) standard to its repertoire. This pioneering framework allows tokens to be seamlessly burned or minted across diverse chains, thereby establishing a unified standard for multichain fungible tokens [42].

The Oracle and Relayer operate autonomously within LayerZero's architectural framework, serving as a bulwark against collusion and misconduct and ensuring the integrity of message delivery. The deliberate separation of block headers and proofs, coupled with the strategic decision not to duplicate and store them all [42], makes LayerZero Endpoints highly efficient and cost-effective, particularly on resource-intensive chains like Ethereum. Additionally, the Libraries contract embedded within the Endpoint outlines communication details for each chain, giving LayerZero the flexibility to quickly expand its support for additional networks.

LayerZero recently partnered with Google Cloud, making it the default oracle provider for decentralized applications seeking cross-chain solutions. This partnership demonstrates Google's confidence in LayerZero's technological capabilities and highlights LayerZero's strategic decision to outsource infrastructure development. LayerZero's strategic approach empowers it to focus on onboarding dApps and cultivating key partnerships while maintaining reliable services. The collaboration is of paramount significance, and LayerZero adheres to a modular approach, providing dApps with flexibility to choose alternative providers or amalgamate various configurations to enhance verification. Consequently, the security profile of each LayerZero protocol may vary depending on the chosen combination of relayer and oracle [43].

In the cross-chain messaging market, competition is increasing, with LayerZero currently leading the race by having the highest number of cross-chain messaging transactions. The distinctiveness of this technology lies in its integration of a diverse range of tokens through its Omnichain Fungible Token (OFT) standards and support for popular cross-chain dApps such as Stargate and Radiant Capital. Axelar, which is positioned to gain broader influence, has recently launched its interchain token service and established

integrations with major wallets such as TrustWallet and MetaMask. Chainlink's Cross-Chain Interoperability Protocol (CCIP) leverages its robust oracle network to secure partnerships with platforms like Aave and Synthetix. The protocol's integration with SWIFT presents a potential game-changer, positioning Chainlink to bridge enterprise chains with real-world assets (RWAs) and carve a niche in this sector.

An example worth noting is the partnership between Onyx by J. P. Morgan and Apollo Asset Management. The objective is to investigate the possibility of cross-chain portfolio management using on-chain tokenized funds and smart contracts. To achieve this, interoperability infrastructure providers Axelar and LayerZero were chosen. This demonstrates recognition from reputable Traditional Finance (TradFi) institutions. This case study highlights the important role that cross-chain messaging protocols are expected to play in future growth [44]. Despite being a relatively new player, CCIP has shown significant potential for growth in both on- and off-chain sectors. Its successful collaborations with SWIFT and other financial institutions in tokenized asset transfers suggest a path towards mass adoption, particularly considering the vast scope of tokenized assets and capital within TradFi.

CONCLUSIONS

Thus, it has been determined that DeFi is forming a new financial infrastructure through decentralization and building on blockchain technology, in which transactions are fast and low-cost, avoiding the need for a third party, and providing free access from different parts of the world.

Functions similar to traditional finance, such as asset exchange, hedging, derivatives trading, borrowing, and lending in DeFi are provided by leading representatives of dYdX, Uniswap, Compound, and Aave.

A key element of user interest and a driver for accelerating the use of DeFi products in 2022 was the bankruptcy of centralized platforms, which prevented the migration of assets to DeFi protocols. The emergence and rapid development of Real-World Assets (RWAs) represent a transformative bridge between Traditional Finance (TradFi) and Decentralized Finance (DeFi). Both short-term dynamics, such as fluctuations in macro interest rates, and enduring catalysts rooted in the efficiency and opportunities intrinsic to DeFi, drive the evolution of the RWA ecosystem. This development represents the first time that physical assets, such as bonds, real estate, and carbon credits, have been integrated into the blockchain.

As time progresses, the collaboration between DeFi-native protocols and TradFi institutions will drive the growth of the RWA ecosystem. Both DeFi and TradFi entities acknowledge the benefits of DeFi and RWAs, such as tokenization, ease of distribution, and increased transparency.

However, for a TradFi-DeFi bridge to be viable, it is crucial to have seamless legal, operational, and structural coordination between physical and digital domains. This coordination necessitates unfettered information exchange and well-defined processes to mitigate potential faults in either domain.

In summary, the investigation into LayerZero, Axelar, and Chainlink's Cross-Chain Interoperability Protocol (CCIP) highlights the complex dynamics of cross-chain messaging and interoperability mechanisms. Each protocol represents innovative approaches aimed at fostering seamless communication across disparate blockchain ecosystems, contributing significantly to the evolving landscape of decentralized technologies. Ongoing research and collaboration are essential for optimizing the potential of these protocols in the growing field of blockchain interoperability.

One should keep in mind the risks inherent in DeFi, because, despite its rapid development and popularity, the sector is in its infancy, with no regulation.

Most of the key DeFi protocols have been in operation since 2020, which suggests that they can pass future stress tests that could lead to asset loss. ■

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