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O. YU. BARKOVSKA
Candidate of Technical Sciences, Associate Professor,
Associate Professor at the Department of Electronic Computers
Kharkiv National University of Radio Electronics
ORCID: 0000-0001-7496-4353

O. A. YANKOVSKYI
Candidate of Technical Sciences, Associate Professor,
Associate Professor at the Department of Electronic Computers
Kharkiv National University of Radio Electronics
ORCID: 0000-0002-1268-0029

P. D. BOTNAR
Postgraduate Student at the Department of Electronic Computers
Kharkiv National University of Radio Electronics
ORCID: 0009-0008-7218-9515

TAXONOMY AND ARCHITECTURAL CLASSIFICATION OF BLOCKCHAIN TECHNOLOGIES: OPPORTUNITIES AND FUTURE APPLICATIONS

Modern centralized computing services do not provide a sufficient level of decentralization, transparency, and scalability, which limits their use in open ecosystems. There is a growing need for a well-founded selection of a blockchain architecture for the development of an efficient computing power marketplace that combines security, performance, and economic viability. The subject of the present analytical study is the architectural characteristics and evaluation metrics of blockchain technologies for building decentralized platforms for computational resource exchange.

The goal of the study is to systematize knowledge of blockchain architecture types, consensus algorithms, and performance metrics to justify the technological basis for the creation of a custom computing power marketplace. The tasks addressed in the paper include: classification of blockchain architectures by openness, consensus type, and scalability approach; comparative analysis of technical, functional, and economic metrics of leading platforms (Ethereum, Polkadot, Hyperledger Fabric, IOTA, Solana); review of existing marketplaces such as Akash, Golem, and iExec to identify their strengths and limitations; and formulation of requirements for a custom solution.

As a result of the analytical review, a systematic typology of blockchain solutions was developed and architectural comparison metrics were generalized with respect to the blockchain trilemma (decentralization – scalability – security). A comparative analysis of five modern platforms (Ethereum, Hyperledger, Polkadot, Solana, IOTA) was conducted in terms of their applicability for a computing power marketplace.

It was found that DAG-oriented architectures (e.g., IOTA) offer higher scalability potential but require improvements in security mechanisms. BFT-based platforms demonstrate high throughput but are limited in terms of open access. Principles for constructing a hybrid architecture based on edge computing were proposed, enabling efficient load balancing, reduced latency, and greater autonomy among participants in a distributed computational environment.

Conclusions: The application of a typified approach to selecting blockchain architecture enables the avoidance of common limitations of existing systems and ensures high adaptability, efficiency, and transparency in the new computing power marketplace.

Key words: *blockchain, marketplace, decentralized computing, DAG, PoS, consensus, metrics, typology.*

О. Ю. БАРКОВСЬКА
кандидат технічних наук, доцент,
доцент кафедри електронних обчислювальних машин
Харківський національний університет радіоелектроніки
ORCID: 0000-0001-7496-4353

О. А. ЯНКОВСЬКИЙ
кандидат технічних наук, доцент,
доцент кафедри електронних обчислювальних машин
Харківський національний університет радіоелектроніки
ORCID: 0000-0002-1268-0029

П. Д. БОТНАР
аспірант кафедри електронних обчислювальних машин
Харківський національний університет радіоелектроніки
ORCID: 0009-0008-7218-9515

СИСТЕМАТИЗАЦІЯ ЗНАНЬ ПРО ТИПИ ТА АРХІТЕКТУРИ БЛОКЧЕЙН-ТЕХНОЛОГІЙ: МОЖЛИВОСТІ ТА ПЕРСПЕКТИВИ ЗАСТОСУВАННЯ

Сучасні централізовані обчислювальні сервіси не забезпечують достатнього рівня децентралізації, прозорості та масштабованості, що обмежує їх використання у відкритих екосистемах. Виникає потреба в обґрунтованому виборі блокчейн-архітектури для створення ефективного маркетплейсу обчислювальних потужностей, який поєднає безпеку, продуктивність та економічну доцільність. Предметом аналізу наданої аналітичної роботи є архітектурні особливості та метрики оцінки блокчейн-технологій для побудови децентралізованих платформ обміну обчислювальними ресурсами. Метою роботи є систематизація знань про типи блокчейн-архітектур, алгоритми консенсусу та метрики ефективності, що дозволить обґрунтовано обрати технологічну основу для створення власного маркетплейсу обчислювальних потужностей. Задачами, що вирішувалися в роботі, є: класифікація блокчейн-архітектур за рівнем відкритості, типом консенсусу та підходом до масштабування; порівняння технічних, функціональних та економічних метрик провідних платформ (Ethereum, Polkadot, Hyperledger Fabric, IOTA, Solana); аналіз існуючих маркетплейсів Akash, Golem, iExec та визначення їхніх переваг/недоліків; формулювання вимог до власного рішення. В результаті проведеного аналітичного огляду сформовано системну типізацію блокчейн-рішень та узагальнено метрики порівняння архітектур із врахуванням трилеми блокчейну (децентралізація – масштабованість – безпека). Проведено порівняльний аналіз п'яти актуальних платформ (Ethereum, Hyperledger, Polkadot, Solana, IOTA) з точки зору їх придатності для створення маркетплейсу обчислювальних потужностей. Встановлено, що DAG-орієнтовані архітектури (зокрема IOTA) мають вищий потенціал масштабованості, але потребують доопрацювання механізмів безпеки. Платформи на основі BFT-консенсусу демонструють високу швидкодію, однак обмежені в контексті відкритого доступу. Запропоновано принципи формування гібридної архітектури з опорою на концепцію edge computing, що дозволяє ефективно балансувати навантаження, знижувати затримки та забезпечувати автономність учасників у межах розподіленого обчислювального середовища. Висновки: використання типізованого підходу до вибору блокчейн-архітектури дозволяє уникнути відомих обмежень існуючих систем та забезпечити високу адаптивність, ефективність і прозорість у новому маркетплейсі обчислювальних потужностей.

Ключові слова: *блокчейн, маркетплейс, децентралізовані обчислення, DAG, PoS, консенсус, метрики, типізація.*

Formulation of the problem

Blockchain technologies have become one of the most discussed topics in contemporary science and the technological landscape. Since the emergence of Bitcoin in 2008 and its subsequent development through smart contracts and decentralized applications (dApps), blockchain has evolved into a foundational technology with the potential to transform numerous sectors of the economy and science. Due to its decentralized nature, data immutability, and transaction transparency, blockchain has become the backbone for financial, logistics, healthcare, governmental, and many other services.

In the context of the digital transformation of public administration and the development of the IT sector, Ukraine possesses significant potential for the implementation of blockchain technologies in areas such as:

- Electronic voting (to ensure transparency and prevent falsification);
- Real estate and land registries (to automate processes and safeguard against unauthorized modifications);
- Medical systems (to protect medical data and ensure rapid access);
- Agricultural sector (to monitor product quality and traceability);
- Educational documents (to verify diplomas, certificates, and similar credentials).

With the increasing application of blockchain systems across various domains, there arises a need for their classification and an in-depth analysis of architectural features. Classical models, such as public blockchains (e.g., Bitcoin, Ethereum), are complemented by private (e.g., Hyperledger Fabric, Quorum) and hybrid solutions (e.g., Dragonchain, XinFin). Moreover, alternative models such as Directed Acyclic Graphs (DAGs) are being developed to overcome certain limitations of traditional blockchains.

Additionally, one of the core challenges is scalability, which affects transaction processing speed and overall system efficiency. Existing solutions, such as sharding, sidechains, and Layer 2 (L2) approaches (e.g., Lightning Network, Optimistic Rollups), help address this challenge but come with their own limitations.

Equally important is the issue of regulatory uncertainty, which impacts the adoption of blockchain technologies across different countries. On one hand, the technology offers transparency and accountability; on the other, it presents challenges related to privacy protection and legal compliance. The use of blockchain in financial, governmental, and private sectors requires further research into legal aspects as well as the adaptation of the technology to meet the requirements of various regulatory authorities.

Analysis of the latest research and publications

The systematization of knowledge concerning blockchain technologies and their architectural characteristics is crucial for the further advancement of this field and the search for effective solutions for integration into real-world application domains. One promising direction is the development of an advanced decentralized marketplace that combines the advantages of existing decentralized platforms while eliminating their shortcomings (e.g., Akash, Golem, iExec) for the purchase and sale of computational resources, cloud services, or data processing through blockchain without intermediaries [1].

The Akash Network – is an open cloud computing marketplace operating on a blockchain based on Tendermint, built using the Cosmos SDK. Akash relies on the Delegated Proof-of-Stake (DPoS) consensus mechanism (Figure 1). The network is secured by a group of validators responsible for block creation, transaction processing, and state changes. Akash's architecture is entirely permissionless: any server operator can become a provider by joining the peer-to-peer network and offering their computing resources through an auction mechanism. This distinguishes it from models where a centralized provider (such as AWS) controls all aspects of infrastructure access [2].

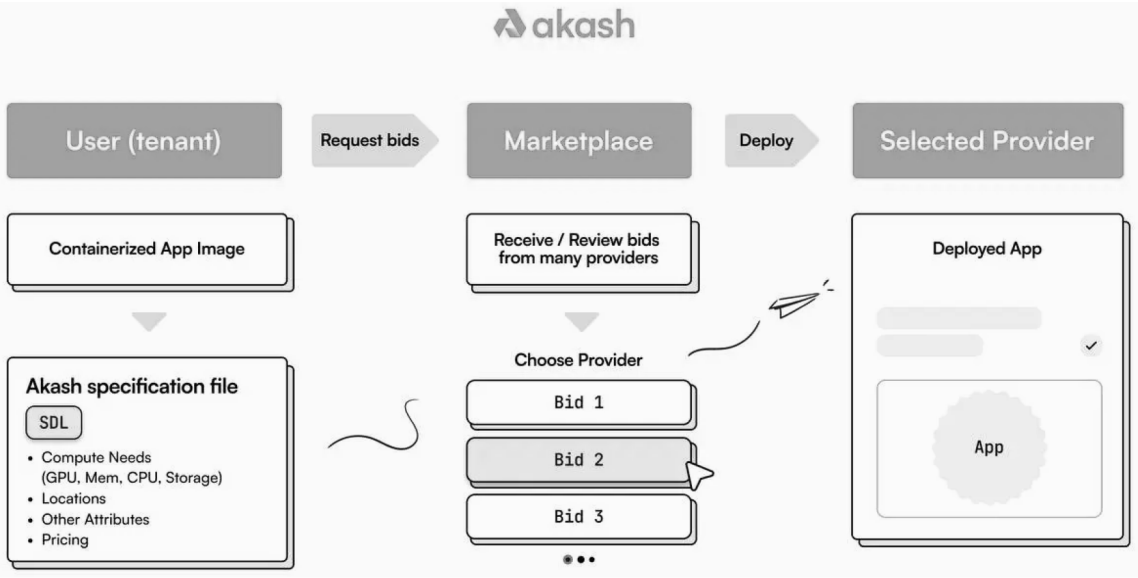

Fig. 1. Simplified Architecture of the Akash Decentralized Computing Platform

(https://daic.capital/blog/akash-network-architecture)

The Golem Network – is a decentralized peer-to-peer computing platform that enables the aggregation of users' resources into a unified "supercomputer." Network participants act as requestors or providers, interacting through encrypted P2P channels using a unified Golem protocol (Figure 2).

The operational essence involves the requestor creating a task by specifying the code and data. The system utilizes Task Templates for typical scenarios (e.g., Blender rendering) or allows the creation of custom templates through the Task Definition Framework. The task is distributed across the network, where providers check the requestor's reputation and submit their offers.

Once the providers are selected, data is transmitted via IPFS, and computations are executed within Docker containers. Results are returned and verified – either through duplicate execution or control checks. Upon successful verification, an Ethereum smart contract facilitates payment in GLM tokens.

Golem comprises the following components:

– Task Manager for task management;
– Task Computer for executing computations on nodes;
– Reputation System for rating nodes based on performance quality;
– Payment System using Ethereum, optimized for micropayments.

The architecture of Golem is effectively a layer built on top of Ethereum: the blockchain ensures transaction transparency and secure payment, while the computations themselves are performed off-chain.

Thus, Golem implements a scalable and secure distributed computing model with flexible task allocation, result verification, provider reputation tracking, and blockchain-based settlements [3].

iExec – is a decentralized cloud platform built on Ethereum that creates a marketplace for computational resources using the RLC token. Computations are performed off-chain, while the entire interaction economy is implemented through smart contracts (Figure 3).

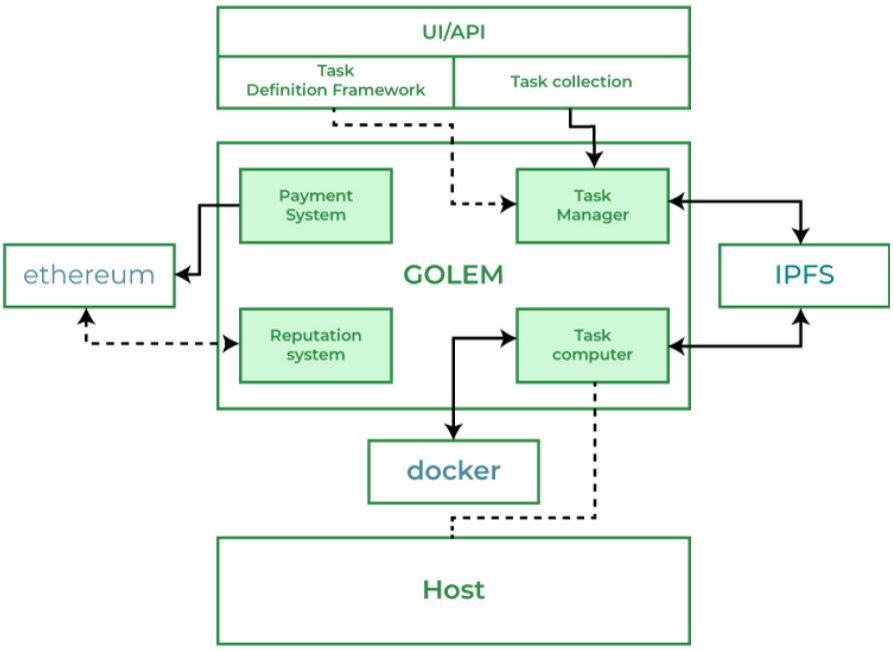

Fig. 2. Simplified Architecture of the Golem Network Decentralized Computing Platform

(https://www.geeksforgeeks.org/golem-network-in-blockchain/)

A key component of iExec is the Worker Pools – groups of computing providers managed by a Scheduler. On the iExec Marketplace, requestors publish orders (specifying price, environment requirements, etc.), while pools submit offers to fulfill these tasks. A smart contract performs the matching of orders, and upon agreement, a Deal is established.

The Scheduler retrieves the task from the blockchain and distributes it among the Worker nodes. Computations are carried out in isolated environments, including support for Trusted Execution Environments (TEEs), such as Intel SGX, which ensure confidentiality and execution integrity.

To verify result correctness, iExec employs its proprietary consensus protocol, Proof-of-Contribution (PoCo). Once verification is complete, the PoCo smart contract unlocks payments to providers in RLC tokens, while dishonest nodes are penalized.

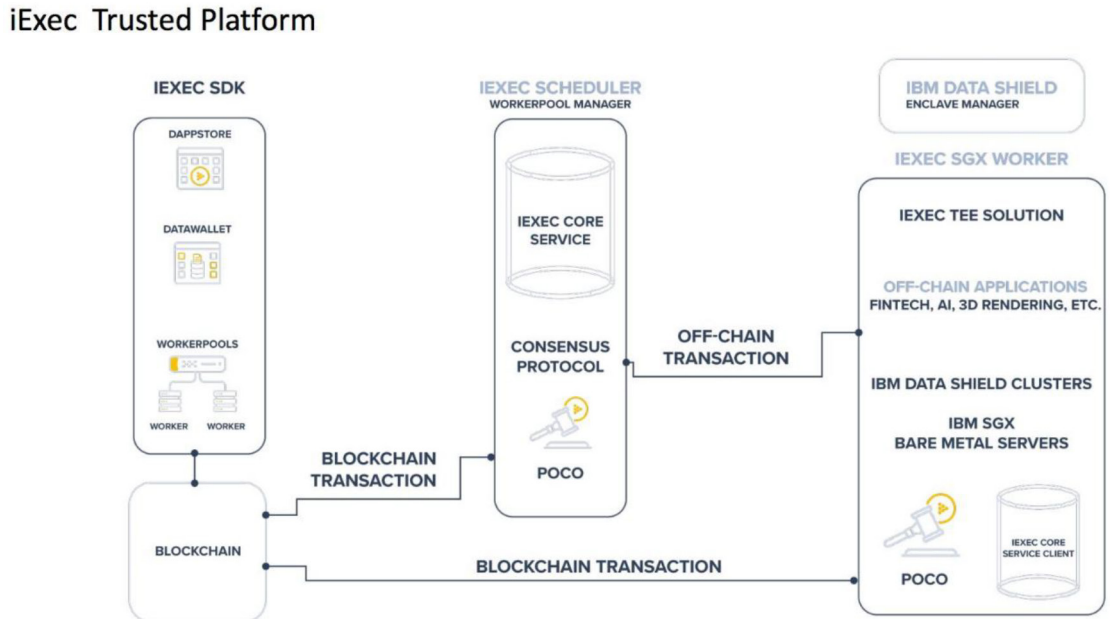

Fig. 3. Simplified Architecture of the iExec Decentralized Computing Platform

(https://x.com/iEx_ec/status/1130883989047320577/photo/4)

iExec supports various roles: requestors, application providers, data providers, and computing providers, all interacting through smart contracts. The architecture is specifically oriented toward enterprise use cases with high requirements for security, trust, and confidentiality [3].

Despite their differing approaches, the reviewed platforms share several common challenges that hinder their efficiency and usability. Specifically, these include: the lack of automated verification of computation results; complexity of integration and use; opaque or overly complex billing models.

Addressing these issues is critical for enhancing the practical applicability of decentralized computing platforms and ensuring their broader adoption across diverse industrial and scientific domains.

Formulation of the purpose of the research

The objective of this study is to systematize knowledge on the principal types and architectures of blockchain technologies, identify their advantages and disadvantages, and assess their application prospects. To achieve this objective, the following tasks must be addressed:

– classification of blockchain architectures by openness level, consensus type, and scalability approach;

– comparative analysis of the technical, functional, and economic metrics of leading platforms (Ethereum, Polkadot, Hyperledger Fabric, IOTA, Solana);

– analytical review of consensus mechanisms (PoS, PoH, BFT, DAG) in the context of constructing a scalable platform for distributed computing;

– analysis of the architectural components of existing marketplaces (Akash, Golem, iExec) and identification of their strengths and weaknesses, formulation of requirements for the development of an original solution.

Presentation of the main analytical review material on blockchain types and architectures

Conducting a detailed analysis of the problem domain, including the systematization of blockchain types and architectures, reduces the risks of developing an inefficient or non-demanded platform by identifying the relevance of existing solutions that align with business objectives (decentralization, speed, security), saving time and costs through the use of proven tools, and providing competitive advantages to the marketplace through optimal UX and functionality [4].

The proposed blockchain typology (Figure 4) serves as an analytical foundation for constructing an effective system, just as it is impossible to chart a good route without knowledge of the terrain.

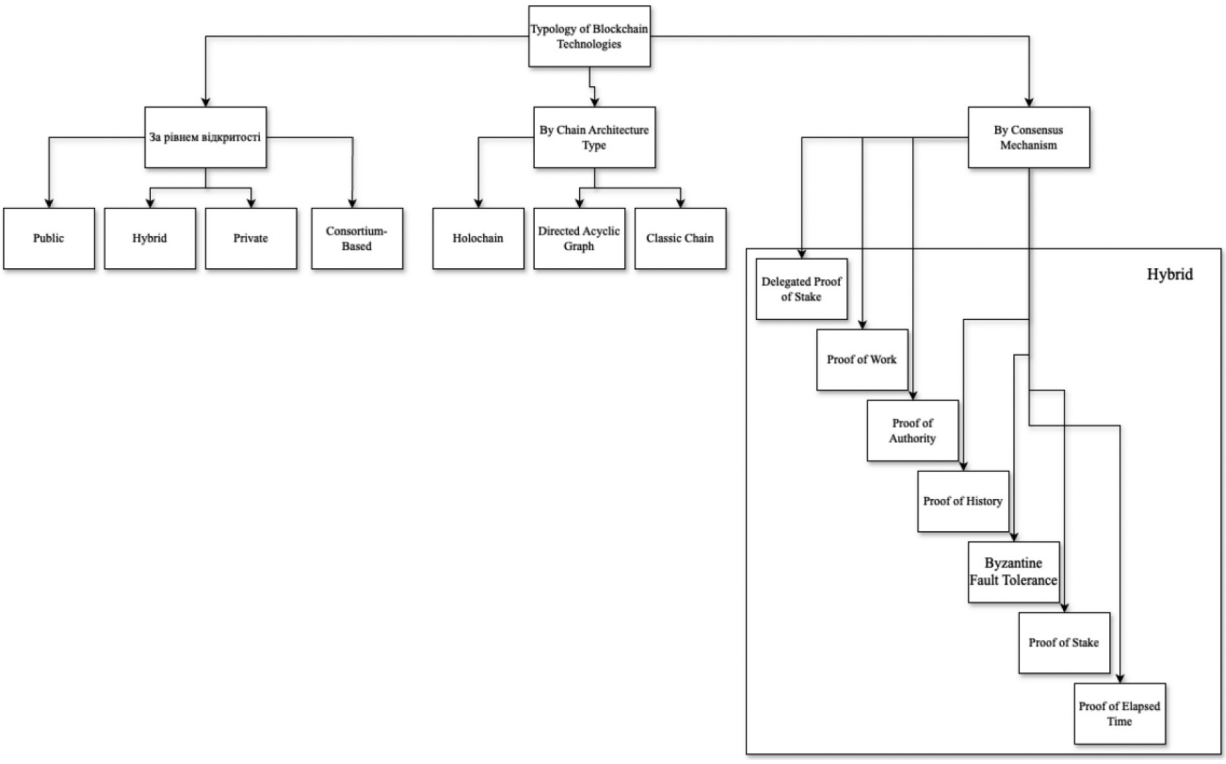

Fig. 4. Proposed Typology of Blockchain Technologies

This typology provides a justified basis for selecting a technological platform according to the requirements of a specific project – ranging from open public networks to private corporate ledgers with modular architectures and specialized consensus algorithms.

Existing blockchain technologies can be classified along two key dimensions: (1) level of openness and governance, and (2) architectural type, considering the corresponding consensus mechanisms.

The classification by openness and governance reflects the degree of participation accessibility in the network and the centralization of governance powers. Four primary types are distinguished:

– Public blockchains – fully open, decentralized systems accessible to any participant without prior permission (e.g., Bitcoin, Ethereum). These are characterized by high transparency and censorship resistance;

– Private blockchains – controlled by a single organization or a clearly defined group of participants. They provide access control and high transaction throughput (e.g., Hyperledger Fabric);

– Consortium blockchains – jointly governed models where multiple organizations share responsibility for maintaining the ledger. Commonly used in financial and logistics systems;

– Hybrid blockchains – combine the advantages of public and private models, allowing control over sensitive transactions while preserving the transparency of the public layer (examples: XinFin, Polkadot) [5].

The classification by architectural type considers the data structure, transaction processing mechanisms, and task distribution approach:

– Classical chain-based architecture – data is organized as a sequential chain of blocks linked by hashes. This is the traditional model, offering a high level of security but limited scalability;

– Directed Acyclic Graph (DAG)-based architecture – a graph where transactions are directly linked without cycles, allowing parallel transaction confirmation and increasing throughput. An example is IOTA, particularly suited for IoT and microtransaction scenarios.

Various consensus algorithms are employed to coordinate the addition of new blocks or transactions to the system. The most common include:

– Proof-of-Work (PoW) – requires computational resources (mining), ensuring high security (Bitcoin);

– Proof-of-Stake (PoS) – relies on token staking instead of computation (Ethereum 2.0);

– Delegated Proof-of-Stake (DPoS) – utilizes a limited set of delegated validators (EOS, Tron);

– Practical Byzantine Fault Tolerance (PBFT) – efficient for private networks with a fixed set of nodes;

– Proof of Authority (PoA) – computations are performed by trusted nodes with known reputations (popular in enterprise networks);

– Proof of Elapsed Time (PoET) – assigns a random waiting time to each network participant (node); the first to complete the wait earns the right to add the next transaction block. This approach avoids endless computations and energy-intensive machines, creating a fair and energy-efficient race where the one who waits the required time wins;

– Proof of History (PoH) – a consensus mechanism used in blockchain networks such as Solana to establish and verify the order of transactions. It works by embedding a verified timestamp into each block, ensuring the network can track the sequence and timing of events.

The selection of a blockchain solution can be guided by a metrics system that enables an objective comparison of blockchain platforms, taking into account technical parameters, costs, functionality, and project context (Figure 5). The optimal choice is typically a compromise between priorities (e.g., security versus speed) and adaptability to future requirements [6].

The accompanying figure presents a systematization of evaluation metrics for multicriteria comparison of blockchain platforms, covering four main classes: technical, functional, economic, and contextual. Such a typology allows assessments to be adapted to various use cases – from high-load computations to document management systems with regulatory constraints [6].

Technical metrics encompass performance (e.g., transactions per second, TPS, and transaction confirmation time), security (consensus type, resilience to attacks), and resource efficiency (energy consumption, hardware requirements). For instance, public blockchains like Ethereum ensure decentralized trust through PoS but exhibit limited throughput, whereas private blockchains like Hyperledger Fabric offer fast transactions at the cost of centralized control. Functional aspects are also essential: support for smart contracts (Turing completeness in Ethereum), interoperability (cross-chain integration in Polkadot), and modular architecture, which allows platforms to be adapted to specific tasks [7].

Economic factors cover transaction costs (e.g., high fees in Ethereum vs. near-zero fees in IOTA), infrastructure deployment expenses, and licensing conditions. Contextual metrics account for domain-specific needs: for the Internet of Things (IoT), scalability and low fees are critical (IOTA); for finance, confidentiality and regulatory compliance matter (Corda); for document management, access control and public auditability are essential (Hyperledger Fabric). Legal aspects such as GDPR or KYC, along with platform maturity (community presence, available documentation), also influence platform selection.

To ensure objective comparison, multi-criteria analysis methods are employed, where each metric is assigned a weight based on project priorities. For example, a DeFi platform would favor Ethereum for its transparency and security, interbank systems might choose Corda for privacy, while IoT solutions may select IOTA for scalability. The key principle is balancing technical capabilities, cost, and adaptability to future requirements, ensuring the resilience and long-term efficiency of the chosen solution.

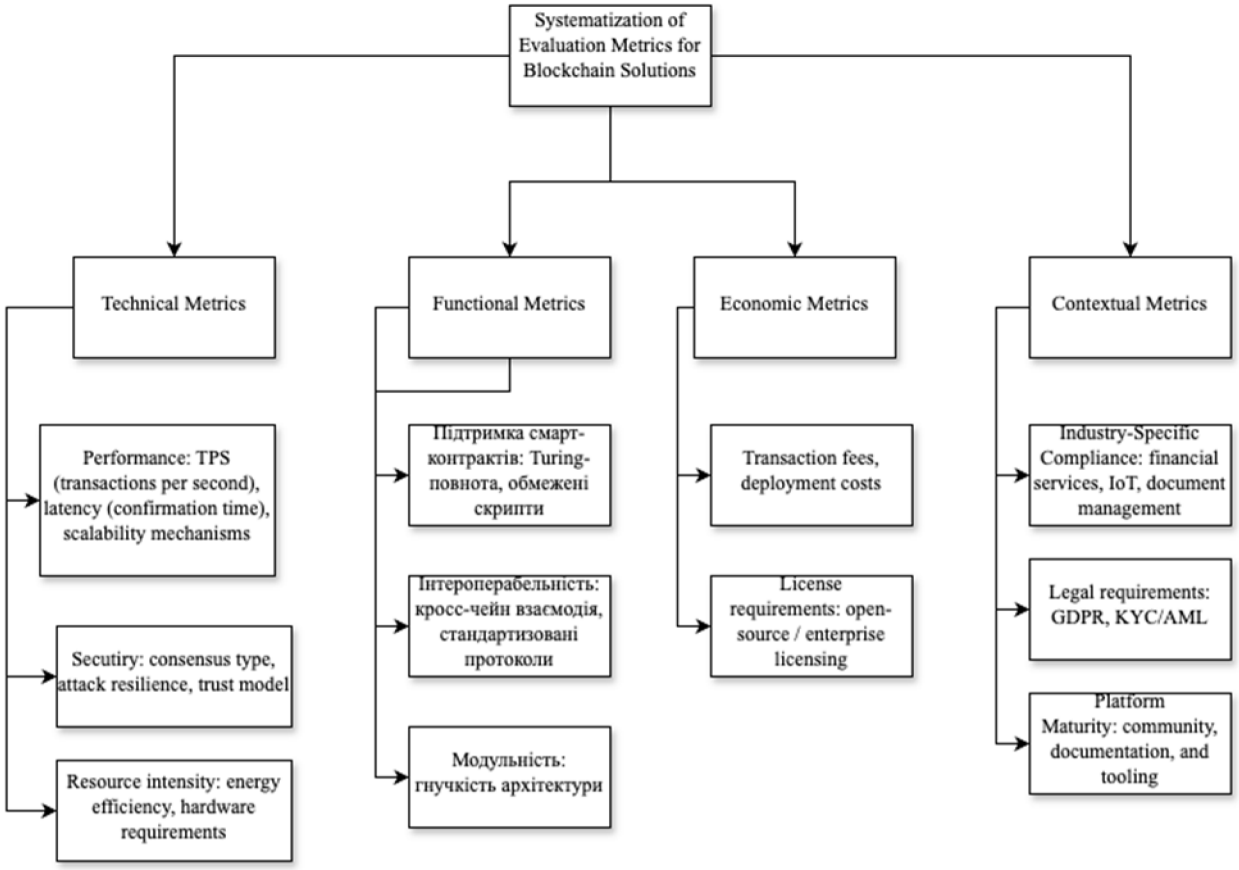

Fig. 5. Systematization of Evaluation Metrics for Blockchain Solutions

To illustrate the differences among various architectures, we examine four platforms:
- Ethereum (a public monolithic blockchain evolving toward modularity);
- Hyperledger Fabric (a private enterprise blockchain with modular component configuration);
- IOTA (a DAG-based ledger, the Tangle);
- Polkadot (a modular multi-chain platform).

Table 1 summarizes the consensus mechanisms, performance indicators, and scalability approaches, followed by detailed analysis.

Table 1

Metrics Analysis of Ethereum

Parameter	Characteristic
Platform	Ethereum (L1)
Consensus Mechanism	Proof-of-Stake (Beacon Chain, since September 2022) with finalization through a validator committee. Previously used Proof-of-Work (Ethash). Validators are selected proportionally to their stake
Performance (Transactions per Second, TPS)	~15 TPS on the base layer. Block creation time ≈12 seconds. Under high load (notably during 2021–2022 peaks), confirmation times and fees increase significantly
Scalability	Scalability is achieved through Layer-2 solutions: Optimistic and ZK-Rollups. Future scaling includes sharding. The base layer (L1) will handle consensus and data availability, while execution moves to rollups. Scaling potential reaches hundreds of thousands of TPS. Ongoing vertical optimizations (e.g., EIP-1559, Danksharding)

These platforms exemplify the trade-offs between performance, scalability, and decentralization across distributed ledger architectures. Ethereum, as a classical monolithic blockchain, offers a high degree of decentralization (with tens of thousands of independent validators after transitioning to PoS) and security but faces the throughput limitations of its base layer (~15 TPS). To address this bottleneck, Ethereum is actively implementing modular solutions (such as rollups), effectively transitioning toward a hybrid architecture where scalability is achieved off the main chain (Table 1).

In contrast, Hyperledger Fabric lags behind public blockchains in terms of decentralization (the network consists of a defined set of participating organizations that trust each other within certain limits), but it radically outperforms them in performance (Table 2). As research has shown, Fabric can exceed Ethereum's throughput by approximately five times or

more, especially under high load, since it does not need to maintain global consensus across thousands of untrusted nodes – coordination between a few organizations is sufficient. This makes Fabric attractive for private corporate applications requiring fast transaction processing (e.g., trading, supply chains), where full network openness is not critical [8].

Table 2

Metric Analysis of the Hyperledger Fabric Platform

Parameter	Characteristic
Platform	Hyperledger Fabric
Consensus Mechanism	Pluggable consensus in a private network. Default: Crash Fault-Tolerant (CFT) algorithms (e.g., Raft); optionally Byzantine Fault-Tolerant (BFT) algorithms (e.g., Istanbul BFT). Multi-phase process: transactions are first endorsed on peer nodes, then ordered via an Ordering Service and finally committed across all nodes. Orderer runs on Kafka (≤ v1.4) or Raft (≥ v2.0)
Performance (Transactions per Second, TPS)	Network-dependent: ~1000–6000 TPS in test environments with few nodes (2–4); ~several hundred TPS with 16 nodes, outperforming public chains. Example: ~5969 TPS in Fabric vs. ~1535 TPS in Ethereum (Geth, private network) under 1000 TPS load. Finalization delays: seconds
Scalability	Highly scalable within a closed network. Fabric scales horizontally by increasing the number of Orderers and resources. However, excessive nodes complicate coordination. Supports channels – isolated sub-networks for specific participant groups. High performance is achieved by operating in a trusted environment with reduced decentralization

IOTA implements a fully decentralized DAG consensus based on Delegated Proof-of-Stake with several hundred open validators (Table 3). IOTA employs a directed graph instead of a chain. Theoretically, the DAG architecture [9] eliminates the "throughput ceiling" imposed by the linear nature of blockchain. The IOTA architecture is designed for ultra-high throughput, and it is expected that the network can handle over 50,000 TPS, with block confirmations occurring within fractions of a second. The DAG-based design of the IOTA platform enables horizontal scalability through parallelism: increasing the number of simultaneous transactions and participants enhances overall network throughput [10; 11].

Table 3

Metric Analysis of the IOTA Platform

Parameter	Characteristic
Platform	IOTA
Consensus Mechanism	Fully decentralized DAG (Tangle): each transaction confirms two previous ones. Consensus mechanism: Delegated Proof-of-Stake + BFT with ~150 open validators. Includes Layer-1 Move-based smart contracts.
Performance (Transactions per Second, TPS)	Consistently Oriented Toward Very High Throughput (> 50,000 TPS)
Scalability	DAG architecture enables horizontal scaling – the more simultaneous transactions and participants, the higher the throughput. Designed for IoT/M2M scenarios with nearly unlimited computational resource scaling. Adaptive fees with burn and validator rewards ensure stability and network security.

Polkadot represents one of the most successful implementations of modular architecture: it achieves high scalability through parallel execution while maintaining a unified PoS consensus layer for the security of the entire system (Table 4). This allows Polkadot to sustain a relatively decentralized foundation (validators are globally distributed, and the NPoS algorithm prevents power concentration in a single stakeholder) while achieving throughput levels unattainable by monolithic chains [12].

Table 4

Metric Analysis of the Polkadot Platform

Parameter	Characteristic
Platform	Polkadot
Consensus Mechanism	Nominated Proof-of-Stake (NPoS) combined with BFT finalization via GRANDPA. Two-tier model: Relay Chain blocks are generated by validators nominated by token holders (NPoS); GRANDPA finalizes blockchain state by signing "super-blocks." Provides fast block production (~6 seconds with Async Backing, 2022–2023) and strong security
Performance (Transactions per Second, TPS)	Parallel transaction processing in 100+ parachains allows >143,000 TPS in stress tests ("Spammening," 2022). Under real conditions, each parachain processes hundreds of TPS, yielding thousands of TPS across the ecosystem. Relay Chain has upper limits (parachain count ~100, block size), capping maximum throughput at hundreds of thousands TPS
Scalability	Very high horizontal scalability. Designed from the outset for modular sharded scaling: each additional parachain adds computational resources. Development underway for Elastic Scaling, which foresees adding a second layer of parachains or fragmenting existing ones for further TPS scaling

Solana is a high-performance public Layer-1 blockchain built for scalability through parallel transaction processing and an embedded "global clock". Solana's key innovation is Proof-of-History (PoH): a periodic verifiable delay function (SHA-256 VDF) that each validator computes to synchronize time without direct node-to-node communication (Table 5).

PoH enables the development of a leader (block proposer) schedule thousands of blocks in advance. Based on PoH, the Tower BFT (a PBFT-like protocol) prioritizes liveness over strict consistency, ensuring that blocks are generated with minimal delays (~800 ms) and the network never halts (i.e., it does not wait for recovery of missing nodes).

Thanks to the combination of PoH and Tower BFT, Solana can handle extraordinarily high transaction volumes: in a test network with ~200 validators, it achieved over 50,000–80,000 TPS, with block confirmation latency of about 0.8 seconds. A summary of Solana's metrics is provided below [13].

Table 5

Metric Analysis of the Solana Platform

Parameter	Characteristic
Platform	Solana
Consensus Mechanism	Proof-of-History + Proof-of-Stake: PoH provides a global time reference (VDF SHA-256) with pre-scheduled leader roles. Tower BFT (PoH-optimized PBFT) finalizes blocks. This design ensures continuous network operation and high TPS
Performance (Transactions per Second, TPS)	Real-world throughput of ~50,000–80,000 TPS with ~0.8 s block time. Average transaction cost: <$0.08. Throughput potential reaches tens of thousands of TPS due to parallel execution
Scalability	Predominantly vertical optimization: throughput increases with hardware performance (GPU, multi-core). Supports mass parallelization of transactions (Sealevel) and efficient block/transaction propagation protocols (Turbine, Gulf Stream). Architecture does not use classic sharding; scaling is driven by embedded optimizations and hardware potential

The comparative analysis of Ethereum, Hyperledger Fabric, IOTA, Polkadot, and Solana highlights that there is no universal architecture that can equally satisfy all requirements. Each platform is optimized for its own set of priorities:

– Ethereum has focused on decentralization and general functionality (smart contracts), gradually improving scalability through modular extensions;

– Hyperledger Fabric prioritizes performance and confidentiality, sacrificing network openness; its architecture demonstrates how efficient a blockchain can be without the "overhead" of full publicness (thousands of participants);

– IOTA and other DAG-based solutions attempt to solve the trilemma through a novel data structure. They have potential for enormous scalability but must overcome security and consensus barriers to reach the reliability level of traditional blockchains;

– Polkadot demonstrates the promise of a sharded approach: dividing work across segments (parachains) significantly increases throughput, while shared PoS consensus guarantees security and inter-chain interoperability. This approach is considered one of the solutions to the trilemma, although its success depends on complex coordination and technological execution;

– Solana is typically applied in high-speed financial services and Web3 applications. Thanks to low fees and minimal latency, Solana is ideal for decentralized exchanges, DeFi protocols, real-time trading, and high-frequency trading (HFT). NFT projects, games, and other decentralized applications are actively developing on the Solana network.

Thus, the further development of distributed ledger technologies proceeds simultaneously in several directions: improving consensus algorithms (e.g., the emergence of hybrid and BFT protocols for public networks), implementing DAG and heterogeneous structures to enhance scalability, and transitioning to modular multi-layer architectures for flexibility [14-15].

Conclusions

The paper conducts a detailed comparative analysis of blockchain platforms (Ethereum, Hyperledger Fabric, IOTA, Polkadot, Solana) and examples of decentralized marketplaces (Golem, Akash, iExec), which allows you to reasonably choose a technological basis for your own solution – a distributed computing marketplace with high performance, reliability, and scalability.

Key architectural differences were identified:

– Ethereum and Solana are public blockchains with sequential block addition (Ethereum transitioned from PoW to PoS; Solana applies a unique Proof of History + PoS);

– Hyperledger Fabric is a private corporate network with modular architecture and Raft/BFT consensus;

– IOTA uses a DAG (Tangle) – transactions form a directed acyclic graph, not a block chain;

– Polkadot offers sharding via a unified Relay Chain and parallel parachains, using Nominated PoS (validators and nominators).

These features determine the degree of decentralization, scalability flexibility, and security mechanisms.

The study of consensus mechanisms and performance metrics revealed specific advantages and limitations. For instance, experiments show that Hyperledger Fabric achieves up to 5 times higher throughput and 26 times lower latency compared to private Ethereum. However, Fabric scales well only up to a certain load (~1000 transactions), while Ethereum in private mode can handle ~10,000 transactions, though with fluctuations due to gas costs. IOTA theoretically offers very high scalability through complete parallelism: in Tangle, there are no blocks – each transaction confirms two previous

ones, enabling nearly arbitrary parallel throughput growth. At the same time, IOTA's real-world implementation still relies on a central coordinator, limiting decentralization and speed. Polkadot ensures parallel processing through parachains, significantly boosting overall network throughput. Solana, with PoH+PoS, achieves extraordinarily high theoretical figures – experiments indicate potential for ~710,000 transactions/sec, given sufficient network bandwidth.

However, one must account for the well-known blockchain trilemma: maximizing scalability, security, and decentralization simultaneously is impossible. For example, increasing speed often requires trade-offs in centralization or resource intensity (as seen with PoW).

The analysis of decentralized marketplace examples – Golem, Akash, and iExec – helped clarify the practical requirements for a computing resource exchange system. These projects demonstrate how issues of trust, incentivizing compute providers (via tokens), and dispute resolution are addressed. Notably, Nardini et al. (2020) developed protocols to ensure fair interactions between parties in a decentralized computing exchange, leveraging blockchain and smart contracts. These developments illustrate both the strengths (decentralized trading of computation without intermediaries) and risks (the need to ensure computation reliability and prevent fraud) of such systems.

The collected data and conclusions enabled a reasoned selection of the technological foundation for the proposed solution, taking into account the strengths and weaknesses of each platform. For example, if the priority is high throughput and low latency among relatively trusted participants, one should consider private DLTs (like Fabric) or systems with BFT consensus. If full openness and decentralization are required, public networks (Ethereum/Polkadot) can be used, with scalability improved through sharding or Layer-2 solutions. DAG ideas (IOTA) suggest possible future architectures with complete transaction parallelism, while PoH/Solana offers mechanisms for rapid validation.

By avoiding known bottlenecks (e.g., coordinator dependence in IOTA or the high costs of PoW), we combine the strengths of predecessors. Thus, the comprehensive analysis provided a scientifically grounded strategy for selecting and configuring the marketplace architecture, preventing the repetition of past mistakes and facilitating the achievement of set goals.

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