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Overview of Blockchain and Cloud Computing Services Integration

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***Abstract*—Nowadays, the adoption of cloud computing has accelerated. Businesses that accepted the cloud in the past few years have increased their usage and now are moving more toward multi - cloud strategies. On the other hand, Blockchain technology increases the trust, security, transparency, and traceability of shared data. Therefore, consolidation of these well-proven technologies promises a great improvement of systems and increased customer satisfaction and security. In this paper, we analyze the advantages of cloud systems and Blockchain technology when they are used separately and the benefits of their merge in one system.**

Keywords—cloud computing, Blockchain, SaaS, IaaS, PaaS, BaaS.

I. INTRODUCTION

In order to provide faster innovation, scalable resources and economies of scale, cloud computing is used. Cloud computing is delivery of computing services over the Internet, including servers, storage, databases, networking, software, analytics and intelligence. When we use cloud services we pay only for the used services. This reduces operational expenses, improves infrastructure management, and enables scaling as a company's needs evolve [1]. We can consider cloud computing as a technology that stores and uses data in various applications and it is controlled remotely without the need to download some computer applications [2].

Data integrity is the basis for providing cloud computing services such as SaaS, PaaS and IaaS. Data integrity refers to enabling data integrity during transactions such as transmission, download or storage to ensure that data is unchanged, accurate and consistent.The data can be changed only in case of an authorized operation over the data [3]. Data integrity means overall accuracy, completeness, and consistency of the data. When data integrity is secure, the information stored in the database will remain complete, accurate and confidential no matter how long it is stored or how often is accessed [4].

Blockchain is a decentralized ledger of transactions, distributed on all computers in one peer-to-peer network (P2P), where all details of transactions are visible to everyone connected to the network. Blockchain increases the trust, security, transparency, and traceability of data shared across a network.

The data structures of blockchain technology have security qualities since they are based on principles of consensus, cryptography, and decentralization. Therefore, merging blockchain technology with existing cloud computing services has great potential for improving data security and integrity, data management, compliance, reliability. In this paper we analyze the customer benefits of the merging of these two well-proven technologies. Since, cloud systems enables different services (Software as a Service, Platform as a Service and Infrastructure as a Service) over a network, we also compare the different incorporation of the Blockchain technology in the services of cloud systems. Also, we present information for cloud providers market share and the distribution of the Ethereum nodes trough the web providers.

II. CLOUD COMPUTING

To access and store data and provide computer-related services over the Internet, cloud computing is used. Simply, it is a remote Internet service that manages and accesses data over the Internet, instead of using some local drives. Data can be anything: images, videos, audio, documents, files, etc. [7].

In fact, cloud computing is the delivery of computing services over the Internet and enables faster innovation, flexible resources, and growing economies. It is a technology used to access various Internet "cloud" services.

Today cloud platforms offer some important benefits that encourage businesses to adopt cloud computing. The most important are:

- **Cost saving -** one of the biggest cloud computing benefits. It provides cost savings as it requires no physical hardware investment. The purchase and management of the equipment is done by the cloud service provider. So, there is no need of trained staff to maintain the hardware.
- **Strategic edge** - it offers a competitive advantage over the competitors. It enables access to the newest applications anytime without spending time and money on installations.
- **High speed** - enables quick deployment of user`s services with fewer clicks.
- **Reliability –** цloud computing allows us to always be able to receive immediate updates on changes etc.[6].

1) Cloud computing services

Cloud system or cloud computing technology refers to the computing components (hardware, software, and infrastructure) that enable the delivery of cloud computing services such as: **SaaS** (Software as a Service), **PaaS** (Platform as a Service) and **IaaS** (Infrastructure as a Service) over a network.

The most flexible cloud computing model **IaaS** is a basic standard service delivery with access to full rights and computing information on-demand. This cloud computing service allows businesses to buy resources on-demand and as-needed, rather than buying hardware completely. The IaaS provider hosts and maintains the computing infrastructure that customers can access remotely.

Customers usually pay for this service by usage or utility bills [11].

The most utilized option for businesses in the cloud market is a **SaaS.** SaaS uses the Internet to deliver applications to its users, which are managed by a third-party vendor. Most SaaS applications run directly through the web browser, meaning they do not require client-side downloads or installations. Users are not responsible for hardware or software updates in this cloud computing service [11,16].

PaaS provides an acceptable framework, software, and tools for the developer to build applications and programs, and to distribute them on the network. It gives a variety of services that help to develop, test, and deploy applications. The customer is not responsible for the cloud hardware such as servers, networks, storage, operating system. The client controls the applications and their configuration [11].

In 2021, SaaS was the leading cloud computing service. It was followed by IaaS and PaaS. In 2022, SaaS is expected to grow at a rate of 20.9 percent, while IaaS is expected to grow at a rate of 18.7 percent [12]. The chart in Fig. 5.1. shows the evolution of the public market share in cloud computing over the last three years and its forecast for 2022.

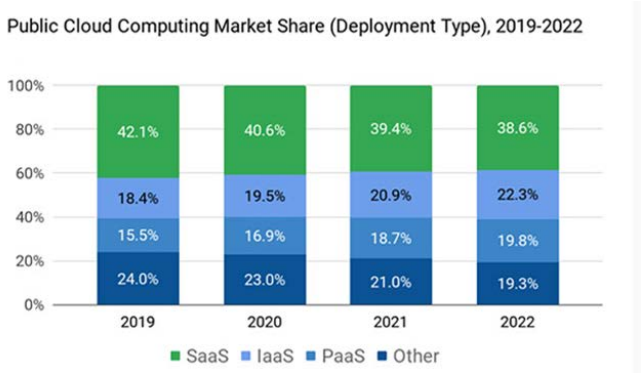

Fig. 1. Public Cloud Computing Market Share [12]

Results of the research carried out in recent years by the Synergy Research Group, are presented in Fig.2. From these results we can see that the market is dominated by 3 large cloud providers that account for 64% of the total share of all cloud service providers. With a 33% market share, Amazon Web Services (AWS) leads Azure with 21% and Google Cloud with 10%. With a slightly lower market share than Google, Alibaba is next.

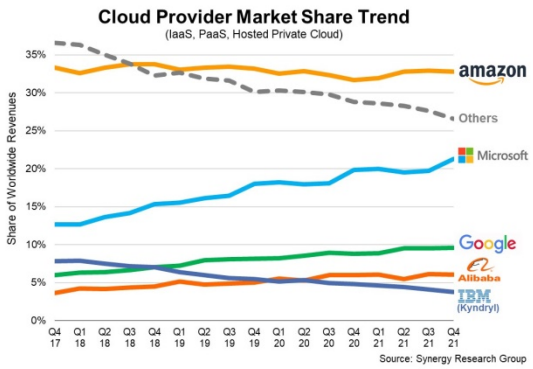

Fig. 2. Cloud provider Market Share Trend [15]

2) Cloud Security Issues

Cloud Computing is still facing many challenges like data security, data management, compliance, reliability. The goal of cloud service providers is to create a secure cloud for customers. A key component of cloud security is focused on protecting the data and business content stored in the cloud. In order to maintain customer trust and protect assets, it is necessary to prevent leakage and theft of data. When choosing a cloud service provider, the user should ensure that the following security requirements are met [8]:

- Controls designed to prevent data leakage
- Strong authentication measures to ensure proper access through strong password controls
- Data encryption
- Visibility and threat detection …

To improve security of the data, easier monitoring of the same as well as improving the interoperability of the system, in this paper we will consider the inclusion of blockchain technology in cloud computing. Therefore, in the next section we will briefly explain the basics and working principles of blockchain technology.

III. BLOCKCHAIN TECHNOLOGY

Blockchain is a shared, immutable decentralized ledger of transactions that facilitates the process of recording transactions and tracking assets in a business network. Blockchain transaction are distributed on all computers in one **peer-to-peer network** (P2P) where all details of transactions are visible to everyone connected to the network. Namely, this is a growing list of linked blocks. Each block in a blockchain network consists of:

- ✓ hash - a unique string of characters assigned to each transaction that is confirmed and added to the blockchain,
- ✓ timestamp - a piece of data that shows the time when the transaction takes place on the blockchain,
- ✓ hash of a previous block that binds the blocks together and protects the block from being modified or prevents insertion of a block between two blocks in the blockchain,
- ✓ nonce (number used once) - a random number that can only be used once, making the process of adding transactions to a large distributed public ledger of existing transactions more difficult.

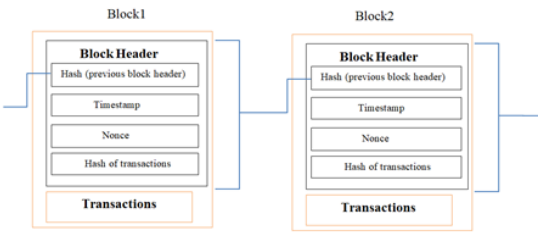

Fig. 3. A simple Blockchain

1) Concept of blockchain

Blockchain`s peer-to-peer network consisting of computers called nodes. The transaction is requested

and broadcast on the blockchain network between nodes. The network of nodes uses known algorithms to confirm the transaction. The transaction is then combined with other transactions, once confirmed, to create a new block of transactions for the ledger. The new block is added to the existing blockchain and with this transaction is complete [5].

Unlike other databases, blockchain also differs from others in terms of its unique features [10]:

• The blockchain network is **decentralized**, allowing the public to participate in the consensus process. The entire blockchain is maintained by each node.

• Each transaction that is verified by the blockchain network is time-stamped and embedded in a block, cryptographically secured by a hashing process that includes the hash of the previous block. It enables the **immutability** of the blockchain.

• The blockchain is **fraud-free**. Transactions that are broadcast will be examined by the nodes, leading to the abandonment of fraudulent transactions. In each round, a block is created by mining. A miner will broadcast a block to the network if they are successful in mining it. The block will be verified by further nodes in the network. Honest miners will reject blocks with fraudulent transactions.

• Blockchain has inherent **security** qualities as they are based on consensus, cryptography and decentralization principles. Each new block of information is linked to all previous blocks in a way that is almost impossible to manipulate. All transactions in a block are verified and agreed upon by a consensus mechanism, ensuring that each transaction is true and correct.

• Blockchain technology enables **user anonymity.** The users of blockchain are protected from the identity theft by having a pair of private and public keys.
Since users only utilize addresses to make transactions, it is challenging to determine who they really are.

• Blockchain provides **auditability**. In order to store user balance information in the Bitcoin blockchain, the Unspent Transaction Output Model (UTXO) is used. Each transaction should reference some previous unspent transactions. During transaction validation, miners check if the referred transactions are uspent.

IV. BLOCKCHAIN TECHNOLOGY IN CLOUD COMPUTING SERVICES

Merging blockchain technology with existing cloud systems have great potential in improving performance, building fully decentralized storage, increasing data security and privacy in cloud systems. Blockchain technology empowers cloud computing through the following [9]:

- ✓ Enhance security in cloud computing. In order to achieve this the technology uses data encryption and hashing.
- ✓ Helps build a decentralized and shared trust model that allows greater transparency. Information once recorded on the blockchain cannot be changed by anyone.
- ✓ Ensures data integrity and authenticity in such a way that abuse of information on one computer does not affect data on other computers. Data stored on the blockchain is permanently stored. It enables simplification of traceability.
- ✓ Cloud computing is based on the centralization of resources. It relies on third-party providers, and it can lead to massive data loss in case of provider failure. Blockchain is a decentralized system (no third party involved) that leads to solution of this cloud computing problem.

1) Blockchain – SaaS – vs – PaaS – vs – IaaS

Blockchain solutions in cloud computing can be delivered through IaaS, PaaS, SaaS, and enterprises should find a suitable alternative for their needs. Therefore, the Blockchain IaaS vs PaaS vs SaaS comparison is necessary to notice the best alternative between them.

BaaS (Blockchain-as-a-Service) is based on the software as a service (**SaaS**) model and works in a similar way. It enables customers to use cloud-based solutions to build, host and manage their own blockchain applications and related blockchain functions.

The notable advantages of **BaaS** are [12]:

- Cost efficiency is a notable benefit with the Blockchain Software as a Service model, as vendors take care of the necessary hardware components, updates, middleware, storage, and servers.
- Blockchain Software as a Service model always ensures high availability of the application.
- The next important benefit associated with the Blockchain SaaS model concerns the facilitated effective maintenance by service providers.
- Blockchain Software as a Service approach facilitates faster deployment times.

Blockchain delivered as **IaaS** has a direct resemblance to the cloud service delivery model. This is a service model in which the vendor configures and maintains hardware required for blockchain applications.

The promising advantages of choosing the IaaS model for blockchain solutions are:

- limited investments in expensive equipment - using on-demand resources improves the cost-effectiveness;
- accessible resources provide good opportunities for increasing effectiveness;
- developer productivity is increased as a result of the cloud provider's ability to deploy and maintain the hardware components for the blockchain infrastructure;
- IaaS's prodigious advancements in scalability and flexibility help shorten development lifecycles [12].

Blockchain **PaaS** service model in which a vendor offers a platform for developing blockchain applications without infrastructure management.

This model offer the following advantages:

- more effective use of time due to new blockchain solutions that are developed, tested, and put into use more quickly;
- increased cost effectiveness due to major maintenance tasks and upgrades by service providers;

- with the Blockchain Platform as a Service model, developers may use blockchain features without any specialized knowledge;
- additionally, Blockchain PaaS enables improved scalability in accordance with the workload;
- Platform as a Service model enables developers to concentrate on extending and enhancing the key functionalities of their applications [12].

Introduced in 2013, Ethereum is one of the oldest and most established blockchain platforms. In Fig. 4 how Ethereum nodes are distributed by cloud web service providers, is given [17]. We can see that the majority of the 4,653 active Ethereum nodes are in the hands of Amazon Web Services (AWS).

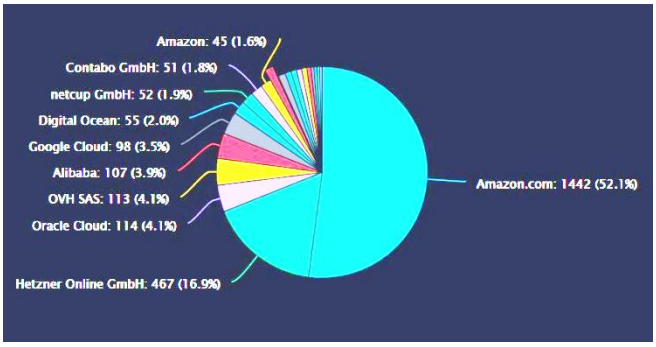

Fig. 4. Distribution of Ethereum nodes from web service providers. (Source Ethernodes)

V. Conclusion

In order to create a secure cloud for the customer, cloud computing services are focused on protecting the data and business content stored in the cloud. For this purpose, the inclusion of blockchain in cloud computing services is essential for their security.

In this paper, we first explain cloud computing services, their advantages and we present information on the representation of cloud computing services in the market share. Then, we analyze the benefits of the integration of Blockchain in cloud computing services. The idea of merging these well-known and widely used technologies is relatively new and very promising. Therefore, after this initial research, we will continue to examine how and how much the different cloud providers are using blockchain technology. It should also be analyzed how satisfied the end users are with this integration and what are the advantages and disadvantages according to them. This analysis will lead to ideas for further research in this field.

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