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Article

Recapitulation Web 3.0: Architecture, Features and Technologies, Opportunities and Challenges

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Abstract: Tim Berners-Lee developed the internet at CERN in early 1990 with fundamental technologies such as HTML, URL, and HTTP which became the foundation of the web. The contemporary web we use today has been much advanced over a period of time ever since the innovation of the World Wide Web was introduced. The static web was the first version of the web, which was the read-only web. Succeeding development in web technology is web 3.0 which is a distributed and decentralized web with emerging technologies. This article emphasizes the comparison of important details with the evolution of the web. The paper also demonstrates the transactional architecture of DApps in networks and decentralized state machines. Decentralization, connectivity, the semantic web, augmented reality and artificial intelligence are the significant features of web 3.0 technology. These features are tremendously used in decision-making on critical issues, which are discussed elaborately in the article. The paper provides various technologies to implement web 3.0 efficiently. The evolution of web 3.0 brings forth opportunities and challenges. The opportunities are the ownership of the data and a personalized web browsing experience. The main concerns are security and scalability requirements for blockchain transactions. The article also laid out the challenges that can be considered for further research.

Keywords: Web 3.0; DApps; Ethereum; smart contracts; blockchain

1 Introduction

Technological advancements and significant use of the internet and web are presenting new challenges as well as opportunities. The World Wide Web and the internet are the most recognized, fast, and main sources of technology for communication worldwide. With increasing development on the web, supporting technology of the internet is also establishing new advancements exponentially with billions of users. The life cycle of WWW has gone through various phases of advancements. Initially, Web 1.0 was static and offered read-only informative features.

Web 1.0 faced numerous problems and challenges that it had to overcome in order to progress into Web 2.0. Web 2.0 is improved into interactive and dynamically informative faces. The next stage of web advancement is web 3.0, which is a union of knowledge representation (KR) and Web technology, which is an association of artificial intelligence [1]. Web 3.0 is advancing at an express speed so that it can provide personalized browsing and portable access to information. The web has had numerous advancements within the last few years. Working with current web-based applications is a completely different experience when compared to initial generations of the web. These advancements of the web over certain periods are divided into different stages such as web 1.0, web 2.0, and web 3.0; Fig. 1, shows advancements in the web.

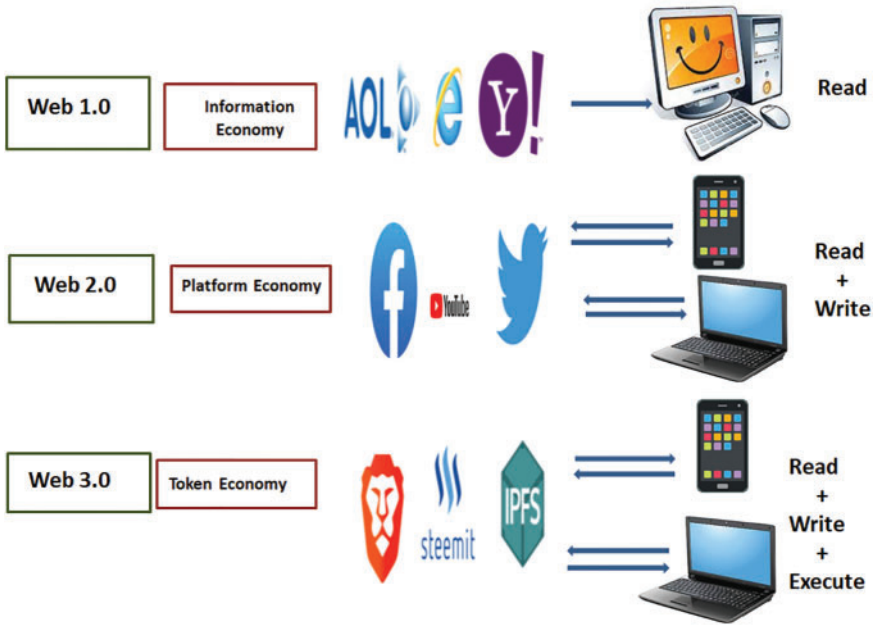

Figure 1: Advancement in the web technologies

Web 3.0 has become a critical topic these days among researchers. The purpose of the article is to define web 3.0 and make a comparison with the previous versions on special characteristics that make it special among all. This paper will give a clear idea of the technologies and their importance as they are implemented through web 3.0. The article also discusses the challenges and opportunities. These challenges can be carried by researchers in the new research direction of web 3.0.

The organization of the paper is arranged in the following way: Section 1 gives a brief introduction to Web technologies. In Section 2 we summarize the previous work done in the past. In Section 3 we demonstrate the architecture of web 3.0. Section 4 presents the features and technologies of web 3.0 and in Section 5 discussed the prospects and challenges of web 3.0 technologies.

2 Related Works

2.1 Web 1.0

The initial state of the World Wide Web refers to Web 1.0. Across the web 1.0 platform, information and data such as text and images are published in a static form [2]. The information shared was a read-only version. Users can only read the content; they could not interact or do much

with the content. Therefore it is considered that the web 1.0 developers as creators and users of web 1.0 as consumers. Open protocols such as FTP for file transfer, HTTP for webpages, SMS for messaging, SMTP for email, and IRC for conversation are associated to construct web 1.0 [3]. HTML protocol and HTTP protocol are connected to communicate with the browser and inform exactly how to display results in a form of text, images, and graphics.

2.2 Web 2.0

The development of internet technology not only refers to advancements in the infrastructure of the web but also provides consumers to create interact and share data and information on the web in a dynamic method [4]. Information-sharing facilities are provided by online software which acts as a rich interface between consumers and the web without the need for additional software installation. Some examples of web 2.0 are Facebook, Wikipedia, Twitter, and many more blogs, where information can be generated and delivered at a high level. With web 2.0 social aspect of using the internet has been changed to social media. Social media allows users to communicate and share information about personal and professional thoughts, opinions and perspectives by using tags, tweets, and likes.

2.3 Web 3.0

Web 3.0 is an extension of already existing technologies present in web 2.0. Internet users can access data effortlessly on the web as content is more diverse, open, and easily available [5]. Web 3.0 is vigorously advancing at a rapid speed, with decentralization as its foundation. In web 3.0 data is hierarchically collected by a machine to categorize it with similar characteristics, machine drives the experience to understand data and catalog data like a human efficiently and effectively. Processed and categorized data can be shared worldwide and understood by any device over any network. Web 3.0 is built on top of crypto-economic systems, which are the next phase of the web. Web 3.0 supports dynamic applications, machine-to-machine interaction, and interactive services utilizing executable levels of the WWW, as shown in Fig. 2, web 3.0 allows processors to analyse data in the same way as users do and develop, disseminate and intelligently relevant content customized as per consumers' requirements [6,7]. Table 1 presents the brief developments between web 1.0, web 2.0, and web 3.0.

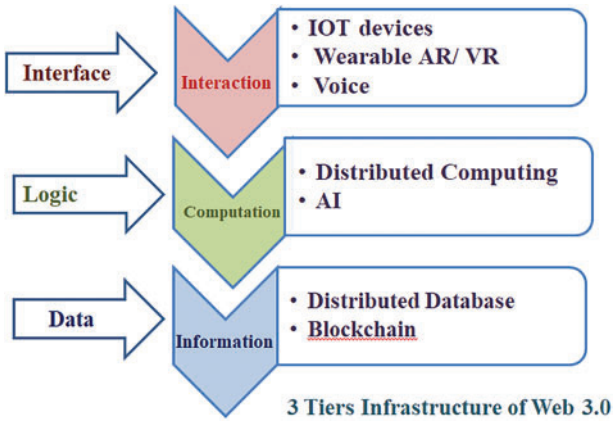

Figure 2: Three tier infrastructure of web 3.0

Table 1: Comparison of web 1.0, web 2.0 and web 3.0 based on various parameters

	Communication	Information	Focus	Personal	Content	Interaction	Search	Research	Technologies	Advertising	Metrics
Web 1.0	Broadcast	Static	Organization	Home pages	Owner ship	Web forms	Directories	Britannica online	HTML/FTP	Banners	Page Views
Web 2.0	Interactive	Dynamic	Community	Blogs/ Wikis	Sharing	Web applications	Keywords/ tags	Wikipedia	Flash/Java/ XML	Interactive	Cost per click
Web 3.0	Engage	Portable/ personal	Individual	Live streams	Curation	Smart applications	Context/ relevance	The semantic web	RDF/RDFS/ OWL	Behavioural	User engagement

3 The Architecture of Web 3.0

Web 3.0 is a decentralized state machine based on blockchain to build applications that run on the internet. Previously web 2.0 was based on middleware technology with a centralized web server as the backend. In web 3.0 data is collectively maintained and controlled by everyone in the network and decentralized state machine. Web 3.0 architecture depends on DApp which stands for decentralized applications. Fig. 3, shows the web 3.0 Transactional Architecture.

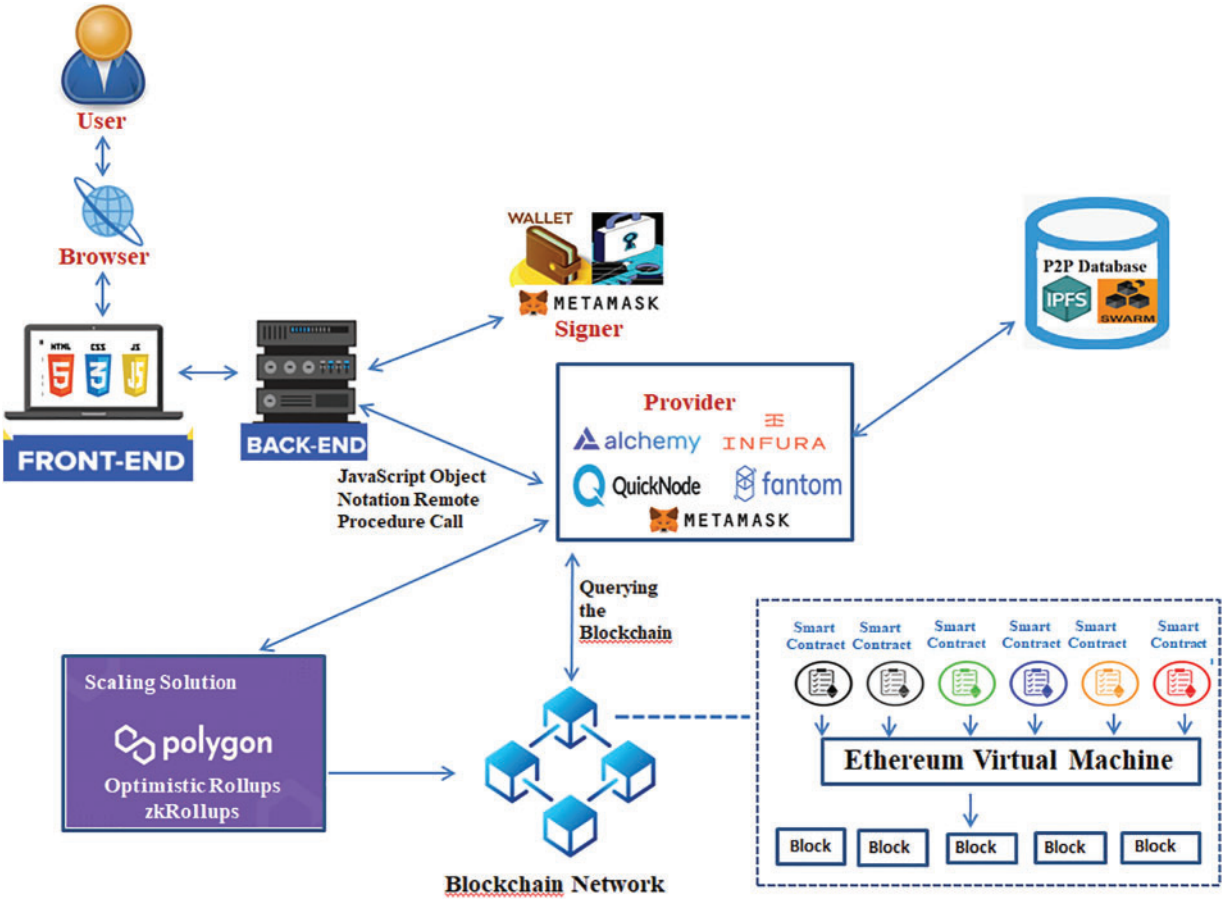

Figure 3: Web 3.0 transactional architecture

3.1 Frontend

The frontend is a Client-side or user-side application that is fetched by using the browser and accelerated to the user.

3.2 Backend

Web 3.0 was established on DApps which are decentralized databases. Blockchain acts as a state machine to distribute applications between networks. The state machine is extended between all the members of the blockchain network. The smart contract is deployed as shared state machines to implement backend logic.

3.3 Third-Party Node Providers

Providers like Infura, Alchemy, and Quicknode deliver the infrastructure of the blockchain network. It is quite a challenging role when there are many nodes in a network. Providers communicate in blockchain networks with JavaScript Object Notation Remote Procedure Call (JSON-RPC) specifications. This RPC is a request-response protocol that specifies the rules and allows the client to request the message to the remote machine, then execute the task and reply to the response to the client.

3.4 Signer

Once the connection is established to the blockchain network through a provider, this state of blockchain can be determined. However, to write to the state, one more step must be done before submitting the transaction to the blockchain which is "sign" the transaction using a private key. This private key is stored in the browser and signs when the client requests a transaction on the blockchain network. Providers like Metamask acts like transaction signers and provider.

3.5 Smart Contracts

Smart contracts are decentralized programs that are written in a high-level language such as Vyper or Solidity, stored and run on the Ethereum blockchain. Since every node in the blockchain network stores smart contract code, anyone on the blockchain network can check and communicate with other nodes on the network.

3.6 P2P Storage Solution

Storing the data in the blockchain is very expensive due to high transaction gas fees, so to some extent, it is reasonable to use non-blockchain distributed and decentralized peer-to-peer storage as a solution. IPFS (Interplanetary File System) or Swarm are widely used peer-to-peer file system that allows storing information across a network of machines.

3.7 Reading Data

Reading of data from the smart contract on the blockchain is done after the signing of transactions and sending them to the blockchain. Reading of data from the smart contract can be approached in two ways: first is Smart Contract Events, where web3.js libraries are used to query and listen for smart contract events. Second is Graph, which is an off-chain indexing solution on the Ethereum platform. The graph uses GraphQL as query language to state which smart contracts to index, which events and functions call to listen, and how to transform incoming events.

3.8 Scaling

With the expansion in the use of blockchain load of transactions, the number of nodes in the blockchain has also increased. At this point, Scalability in the blockchain is a big challenge as it has to deal with different factors such as capacity and cost, throughput and networking, etc. Polygon and L2 are introduced as scaling solutions for blockchain scalability. Polygon has a secondary blockchain which is called a sidechain that interfaces with the main chain and that processes and executes transactions. Another solution for blockchain scalability is the L2 solution which is Optimistic Rollups and zkRollups. L2 solution is similar to the Polygon solution, here batch transactions off-chain using a "rollup" smart contract and then periodically commit these transactions to the main chain.

4 Web 3.0: The Features

4.1 Decentralization

The problem with web 2.0 was the centralization of the data in the company's servers. Due to this, the major players in social network companies like Google, Facebook, and Amazon owned all the user's data and used it for the benefit of the company without the intervention of the users who were generating it. The main breakthrough of web 3.0 is to decentralize the users' data and break the monopoly of the above-mentioned companies' ownership [8]. Decentralization of the data enables users to govern the permissions on their data rather than intermediary companies. Therefore, technically, the decentralization of the data is the privacy of the user's data. DeFi (Decentralize Finance) is another critical component of decentralization, in which users conduct money transactions without the intervention of financial firms.

4.2 Connectivity

Web 3.0 not only enables the connectivity of people but also devices. The Internet of Things (IoT) is one of the examples of web 3.0 connectivity features. The IOT includes the connectivity of smart appliances such as refrigerators, home security systems, and wearable devices like smartwatches, and Alexa. IoT helps create a web of all the connected devices, which enables users to make their life more comfortable and secure. This technique is transforming a wide range of fields, from medicine to decision-making on critical issues.

4.3 Semantic Web

The semantic web is the term coined by Tim Berners-Lee as an extension of web technology in the context of web 3.0. The semantic web helps in creating a stack of vocabulary to understand the human language along with the emotions shared on the web, more accurately [9]. The data created by the semantic web are linked with each other in the form of data stores, vocabulary stacks, and data handling rules. Linked data are empowered by technologies like RDF, SPARQL, OWL, and SKOS. The semantic web helps in making decisions based on the data which has more pictures, signs, and symbols than text. This feature makes the semantic web one of the most powerful tools in web 3.0.

4.4 Augmented Reality (AR)

Augmented reality is a 3D vision technology, which has already made a crucial space in web 3.0 implementation [10]. This technology is already used in gaming applications, but now it is more than just an entertainment feature. Apart from gaming applications, industries such as manufacturing, e-commerce, and real estate are adopting AR for their business objectives in a wide range. For instance, while buying some property, the buyer does not need to visit the property physically. Instead, he/she can review it through AR tools and get a real-time experience of the property. The technology empowers

users to speed up their services with reduced stress. Healthcare has made a huge change in the field of surgery. The visualization of the surgical site enables surgeons to do the surgery remotely. Although AR technology is new to healthcare, but is gaining popularity these days. Technically, there is no field where AR is not making an impact in improving the users' experience of doing work.

4.5 AI

AI is one of the fundamental building blocks of web 3.0. AI helps the system to collect all the user's data and recommend activities for the users and predict the possible behaviour of all the users on specific activities. An AI-based recommender system truly helps the users and the companies also to manage their businesses and offer options based on individual users' choice. By applying an AI algorithm, advertising companies analyze the preferences of their customers and populate their systems with personalized advertisements. This persuades users to buy the items that are more relatable to their choices, thereby improving the sales of the company.

5 Web 3.0 the Technologies

5.1 Blockchain

Web 3.0 offers a great deal of security and privacy to the user's data by decentralizing it. Blockchain is the technique, that helps the data to be decentralized and hence improves the privacy and security of the data as well. Blockchain data can be shared without monopolizing a few service providers. The users will have ownership of the data and without the consent of the data owner, it cannot be utilized by anyone. This technique also enables the movement of information, assets, and money without the interference of a third-party middleman [11]. This technique distributes the data in various "blocks" and "chains" them to the parent block to maintain the connection and reference for the users cryptographically [12]. The data saved in the block cannot be changed without affecting all the previous blocks to maintain the uniformity of the data. Each transaction should be added to the computer networks chained for sharing of the data. The machines, which are chained together to share the information is called node. Nodes are responsible securing the integrity and consistency of the data shared with all the users.

5.2 Smart Contracts

Smart contracts are self-executing codes that contain the agreement between the seller and the buyer, which is automatically verified and implemented through the computer network. These are saved in a decentralized blockchain environment, where they are secure and irreversible but trackable. The smart contract is a collection of data and code that resides at an address on Ethereum. These are the most trusted agreements carried out secretly among anonymous parties without the need for any financial organization or legal system. These transactions are done through blockchain techniques, which are encrypted and make them very difficult to hack. The smart contracts can be programmed by the developer to be simpler for the user to understand.

5.3 Ethereum Virtual Machines

EVM is a set of codes that executes smart contracts and maintains the state of machines linked to those smart contracts, known as the Ethereum network. This code is executed whenever a transaction is executed, and a new block is added to the Ethereum network. The EVM converts the smart contract into a readable format called 'Bytecode'. This is the place where all the Ethereum accounts and smart contracts reside. The EVM defines the rules for managing the data and the rules to change the state of

the node while recording the transactions and adding the blocks to the existing chain [13]. EVM also poses as a platform for developers to create decentralized applications (DApps).

5.4 Cryptocurrency

Cryptocurrency is a digital or virtual currency, created using encrypted algorithms. Cryptocurrencies operate without any monetary regulation organization, such as banks. To keep cryptocurrency, users need to have a cryptocurrency wallet, that can be accessed via their mobile devices or laptops in the cloud. Crypto wallets are the tools in which encrypted data are saved and can be accessed by confirming the owners' identity. Blockchain technology is used to keep track of transaction that happen among currency users. It's a peer-to-peer interaction that allows anyone to send and receive money from anywhere. Cryptocurrency transactions are purely an online interaction saved in a database, rather than an exchange of physical money. The transaction is recorded in a public ledger, which can be accessed by the parties involved in the transaction. One of the biggest examples of cryptocurrency is Bitcoin. Nowadays, Bitcoin is accepted by many companies for their transactions.

5.5 Edge Computing

The challenge in the implementation of web 3.0 is speed and storage. Edge computing decentralized architecture is playing a vital role in managing these two challenges. Edge computing foundational technology supports heavy web 3.0 applications to work efficiently [14]. It enables the processing of the data as near as to the source of the data hence decreasing latency and bandwidth use. Edge computing processes the data in a local location such as a user's PC, or an IoT device before relocating them to the cloud. This reduces the stress on the network and increases the utilization of resources available locally, therefore, reducing the stress on the servers also. Due to the massive use of IoT devices, the data generated has increased manifolds. Edge computing provides a satisfying solution to manage such types of data along with saving bandwidth and faster data delivery speed.

6 Web 3.0: Opportunities and Challenges

6.1 Opportunities

6.1.1 Data Ownership

In web 2.0, the data generated by the users is being exploited by giant corporations such as Facebook, Google, Amazon, etc. At times, personal information is also shared by social media companies without the knowledge of the data owner. With the advent of blockchain technology in web 3.0, the end user will have full control over the data they generate by doing various activities on the internet. The user can opt for the data to be shared or keep private. The user can even earn money by sharing their data with advertising companies. So, the data will be the sole property of the owner and handled by them completely.

6.1.2 Uninterrupted Services

Due to the decentralization technique in web 3.0, the data will be stored on distributed nodes. Therefore, the problem at some specific nodes will not interrupt the services or work of the users. In various decentralized networks, there is a mechanism to fine the validators for exceeding the standards. This feature of an uninterrupted supply of service makes the use of web 3.0 more productive and result oriented.

6.1.3 Personalized Web Browsing Experience

One of the critical advantages of using web 3.0 is to get a personalized environment while browsing the internet. Web 3.0 analyses our interest and requirement of browsing activity and maintain a profile for our internet browsing preferences. It will offer a more personalized internet browsing experience since websites will be able to recognize our interests. Web applications investigate our use and browsing habits to be personalized and better adapted to our device, location, etc.

6.2 Challenges

6.2.1 Mass Adoption

Accepting a change is not an easy process for humans. Since blockchain or decentralization technology is not very popular currently, the adoption of this technique by the masses is a big concern. People are not more concerned about the use of their browsing data by various companies for their personal use. Today's centralized social media platforms, such as Facebook and Twitter, have grown extremely popular among the public. Legally, the companies cannot use the browsing data of the users, so they pop up with a message accepting cookies from them. In this agreement, they obtained the consent of the customers to use their data for promotional purposes. Understanding this trait of companies by the users will take time. The services provided to decentralize the data may cost some money. People may object to the concept of replacing the present platform with a blockchain-based application since they are getting the services for free [15]. Unless they have a reasonable and personal requirement for the decentralized web, people may take time to decide on this big change.

6.2.2 Security

Blockchain technology is identity-less and trust less and open to all. Hence, web 3.0 remains exposed to certain cyber-attacks such as DDoS, DNS hijacking, and sniping bots. DDoS attacks' biggest threat to the blockchain is focused on the protocol layer by flooding transaction. These attacks slow down the operations and give attackers access to modify the blockchain ecosystem. There are a few more attacking techniques that can make smart contracts behave unexpectedly. Re-entrancy is one type of attack that makes the main function call execute recursively, resulting in an indefinite loop. A short address attack is another fatal attempt to send imprecise arguments from the EVM to dispatch specially crafted addresses, which results in the exploitation of smart contracts [16]. The hackers may target personal information and digital assets such as artifacts, and cryptocurrency. Hackers can infect smart contracts with malware, which can lead to massive financial loss without any trace of identification.

6.2.3 Scalability

Blockchain technology keeps the storage of each transaction in a block and chains them together. This means that if there are more transactions, there will be more blocks that are surfacing the problem is scalability. This problem came into view through a game "Growing Kittens" on the blockchain. The number of players increases in the game led to an increase in game fees and made the game expensive [16]. In the current scenario, this issue is still unresolved. The developers are expecting to get a solution by introducing an additional layer to offload blockchain transactions.

7 Beyond Web 3.0: The Future

Web 4.0 is expected to be fully managed by AI and machine learning techniques that are programmed based on human behaviour. It will be more of M2M interactions such as auto-configuring,

auto-designing, and auto-recommending for various business models. The main vision of web 4.0 is to require less interaction with humans to do any task. The human experience will be envisioned in the machines using AI techniques and the rest will be taken care of by the machines themselves without human intervention. According to recent studies, most of the application-based on web 3.0 is using blockchain for various activities. The data generated by the blockchain is so huge that we need to use ML and AI techniques to process the information. The Fig. 4, explains the techniques that have been used since the era of web 1.0 until web 3.0 and beyond.

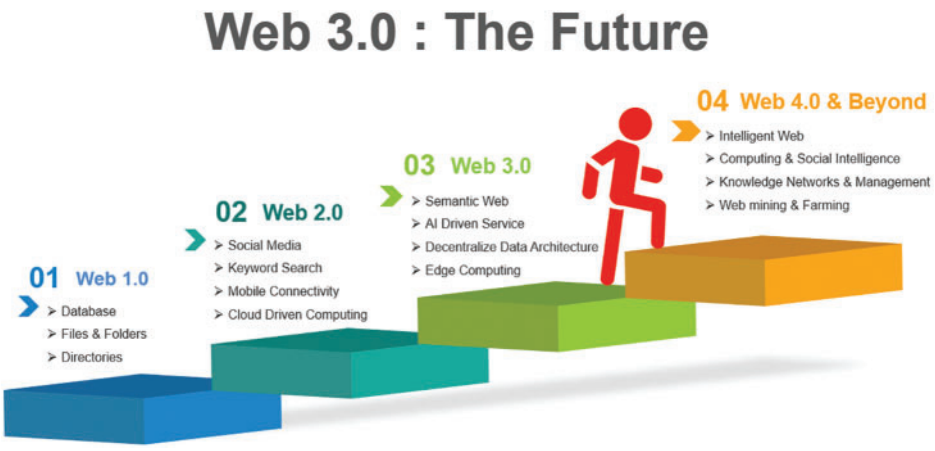

Figure 4: Explains the techniques used in web 1.0 until web 3.0 and beyond it

Web 4.0 will be pronounced as an intelligent web, as it will handle all the activities by machine and AI techniques. We can categorise web 1.0 as "Read Only", web 2.0 as "Read-Write" and web 3.0 as "Read-Write-Execute". The main features of web 4.0 are expected to be an intelligent social web, a big hub of decentralized knowledge networks with self-management features. Web mining and farming will be the additional feature and applications, which can help to enhance the performance of the web as shown in Table 2.

Table 2: Web 4.0 features & applications

	Web 4.0
Features	• Brain-computer interfaces (BCIs) • Artificial intelligence • Augmented reality • Metaverse • Internet of things
Applications	• It will focus on personalization and make new opportunities for social networking and online collaboration. • Advancement of multimedia content in web 4.0 to make it embed multimedia content into websites for better user experience. • The main focus is on AI and machine-based analysis of data.

8 Conclusion

Web 3.0 is not only a collection of applications and innovative technology but also services. The world wide web has experienced all three iterations of web 3.0 from merely static pages of information, to interactive pages and now communicating and consuming the information. Web 3.0 offers more safety and ownership of the data to the users generating it. Web 3.0 endeavors to use AI, ML, IOT technologies to give a premier experience to users. Users can share the data generated by them and earn a good amount of rewards in return. This paper discusses the complete details of the evolution of www from web 1.0 to web 3.0. It elaborated the architecture of web 3.0 working details step-by-step. Further, this paper covers the most identified features and tools, and technologies of web 3.0. The article discusses the most eminent feature of web 3.0 such as decentralization, semantic web, and most popular applications like blockchain, smart contracts, and edge computing. Web 3.0 is still in its initial phase. It has a long way go before proving its usability. The article is concluded with a detailed discussion about the opportunities and challenges in the future path of web 3.0 to success. Although the adaptation of Web 3.0 is a big challenge, it will prove to be a major paradigm shift for the technology world.

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