



International Journal of Learning and Change

ISSN online: 1740-2883 - ISSN print: 1740-2875

<https://www.inderscience.com/ijlc>

A comparative analysis of Web 3.0, Web 2.0, and Web 1.0: evolution and implications

Lakshmi Mansi Chada, Hari Vishnu Parashar, Ishi Singh, Mishti Rastogi, Suvin Singh, S.P. Raja

DOI: [10.1504/IJLC.2025.10068202](https://doi.org/10.1504/IJLC.2025.10068202)

Article History:

Received:	07 December 2023
Last revised:	30 March 2024
Accepted:	11 May 2024
Published online:	30 December 2024

A comparative analysis of Web 3.0, Web 2.0, and Web 1.0: evolution and implications

Lakshmi Mansi Chada, Hari Vishnu Parashar,
Ishi Singh, Mishti Rastogi, Suvin Singh and
S.P. Raja*

School of Computer Science and Engineering,
Vellore Institute of Technology,
Vellore – 632 014, Tamil Nadu, India
Email: clakshmimansi@gmail.com
Email: harivishnu.parashar2021@vitstudent.ac.in
Email: ishi.singh2021@vitstudent.ac.in
Email: mishtirastogi.work@gmail.com
Email: mishti.rastogi2021@vitstudent.ac.in
Email: suvin.singh2021@vitstudent.ac.in
Email: avemariaraja@gmail.com

*Corresponding author

Abstract: For ages, humankind was unsuccessful in accomplishing their aspirations practically, though sometimes they were able to achieve the same theoretically. However, this gap was bridged by many groundbreaking inventions. One such invention is the World Wide Web. The web, which is often described as an evolving network of networks, has constantly been moving forward since its discovery and thereby giving rise to improved applications. This review paper aims to elucidate the reader on the same. It provides a comprehensive understanding of each iteration of the web and talks about the technological advancements made considering that specific version of the web. The outcome of this review is to present the reader with a comparative analysis of all the iterations of the web based on certain chosen parameters. Furthermore, the findings of this review have been discussed from various aspects to help the reader gain a better understanding of the comparative analysis.

Keywords: Web 1.0; Web 2.0; Web 3.0; decentralisation; blockchain; API; user experience; architecture; implications; limitations.

Reference to this paper should be made as follows: Chada, L.M., Parashar, H.V., Singh, I., Rastogi, M., Singh, S. and Raja, S.P. (2025) 'A comparative analysis of Web 3.0, Web 2.0, and Web 1.0: evolution and implications', *Int. J. Learning and Change*, Vol. 17, No. 1, pp.1–55.

Biographical notes: Lakshmi Mansi Chada is currently pursuing her BTech in Computer Science from Vellore Institute of Technology, Vellore. She is deeply passionate about the intersection of technology and society, particularly focusing on cyber security, artificial intelligence, and data science. she actively engages in open-source development and is motivated by community-driven solutions which create impactful digital innovations. As she advances in her academic journey, she is dedicated to continue research and development in her areas of interest.

Hari Vishnu Parashar is a gifted person who has a love of Technology and Computer Science. He is renowned for his commitment to studying and his great work ethic and is presently pushing for a Bachelor of Technology degree in Computer Science at the esteemed Vellore Institute of Technology. Due to his expertise in this field and his specific interest in web development, Madhusudan has established a solid reputation as a gifted and imaginative developer. In addition, he has a strong interest in machine learning and problem-solving and is constantly keen to explore new ideas and techniques in this fascinating area.

Ishi Singh is a student of Vellore Institute of Technology, Vellore, is currently pursuing her BTech in Computer Science. She strives to solve real-world problems through the fusion of technology and innovation. With a keen interest in machine learning, data science, and AWS Cloud, she aims to contribute to addressing practical challenges and making a positive impact on society. Alongside her technical pursuits, she is deeply passionate about design and sketching, serving as the Design Head of the Executive Board of the IEEE Computer Society chapter of VIT. Committed to advancing her academic journey, she remains dedicated to further research and development within her areas of interest.

Mishti Rastogi is a passionate third-year computer science student with a knack for problem-solving and analytical thinking. From a young age, she been captivated by technology's potential to shape the future. Her journey in computer science began with a spark of curiosity that evolved into a burning passion for programming languages and software development. She is a strong advocate for diversity and inclusion in the tech industry, supporting initiatives aimed at encouraging underrepresented groups in STEM. With her commitment to excellence and dedication to learning, she poised to make a significant impact in the world of computer science and beyond.

Suvin Singh is a passion-driven computer science student at VIT Vellore. He is currently working as an AI Products Engineer to solve real world problems. He has explored and worked in the field of data for more than one year and have expertise in data analytics and designing data science-based solutions. He works with ML/DL based research projects.

S.P. Raja completed his schooling in Sacred Heart Higher Secondary School, Sathankulam, Tuticorin, Tamilnadu, India. He completed his BTech in Information Technology in the year 2007 from Dr. Sivanthi Aditanar College of Engineering, Tiruchendur. He completed his ME in Computer Science and Engineering in the year 2010 from Manonmaniam Sundaranar University, Tirunelveli. He completed his Ph.D. in the year 2016 in the area of Image processing from Manonmaniam Sundaranar University, Tirunelveli. Currently he is working as an Associate Professor in the School of Computer Science and Engineering in Vellore Institute of Technology, Vellore, Tamilnadu, India. He published 150 papers in international journals, 24 in international conferences and 12 in national conferences.

1 Introduction

The World Wide Web, commonly referred to as the web, is the groundbreaking innovation of the internet. The motivation to bridge the gap between the developing computer technologies and computer networks led to its invention (Berners-Lee et al., 1999). As computer technologies advanced, the web had to undergo significant modifications to enable the computer networks to transfer and process data globally. Subsequent to its developments at each stage, the web has seen its applications in various fields. This has indeed had a profound effect on how we access, share, and communicate information (Berners-Lee et al., 1999) and has transformed business, technology and multiple dimensions of the society (Ritzer, 2019). Each iteration of the web has its unique applications and represents a distinctive stage in its advancement. As we employ the web frequently in our daily lives, it underscores the importance of understanding its origin and evolution. This review paper aims to expound upon the same for the reader. To understand the evolution of the web, it is important for us to know general and comprehensive information about each iteration of the web. By understanding the background and characteristics of each iteration of the Web, we establish the foundation for comprehending the motivations and advancements of the next versions of the Web that have been brought to the digital landscape. To facilitate the same, this review paper presents and examines the definition, characteristics, technological aspects, user experiences (UX), implications and potential benefits of each web generation. For instance, the background of Web 1.0 and Web 2.0 provide valuable context for understanding the evolution of Web 3.0 and the driving forces behind its inception.

The primary objective of this review paper is to provide the reader with a comparative analysis on the different iterations of the web. To prepare the foundation for the same, this review paper presents a comprehension on the transition from centralised and static web platforms to user-centric and participatory environments. The transformation of the Web into decentralised and trust-enhancing ecosystems can be observed by studying the comparative analysis provided in this review paper. The descriptive comparative analysis has been made by employing certain parameters that have been chosen pertaining to certain attributes like architecture, user experience, applications, limitations, integration possibilities, ethical considerations, and societal impacts. The detailed outline of this review has been presented in this article to guide the reader through this study. Figure 1 displays the mentioned outline. Furthermore, the findings of this review have been discussed in detail. The findings have been analysed from various dimensions such as scalability, interoperability, security and privacy, decentralisation, accessibility, usability and the socio-economic impacts. This approach has been employed to enhance the reader's grasp of the findings of the review. Additionally, the review has been summarised for the reader's convenience, offering a brief overview of this study. This summary aims to aid the reader to comprehend the overall essence of the comparative

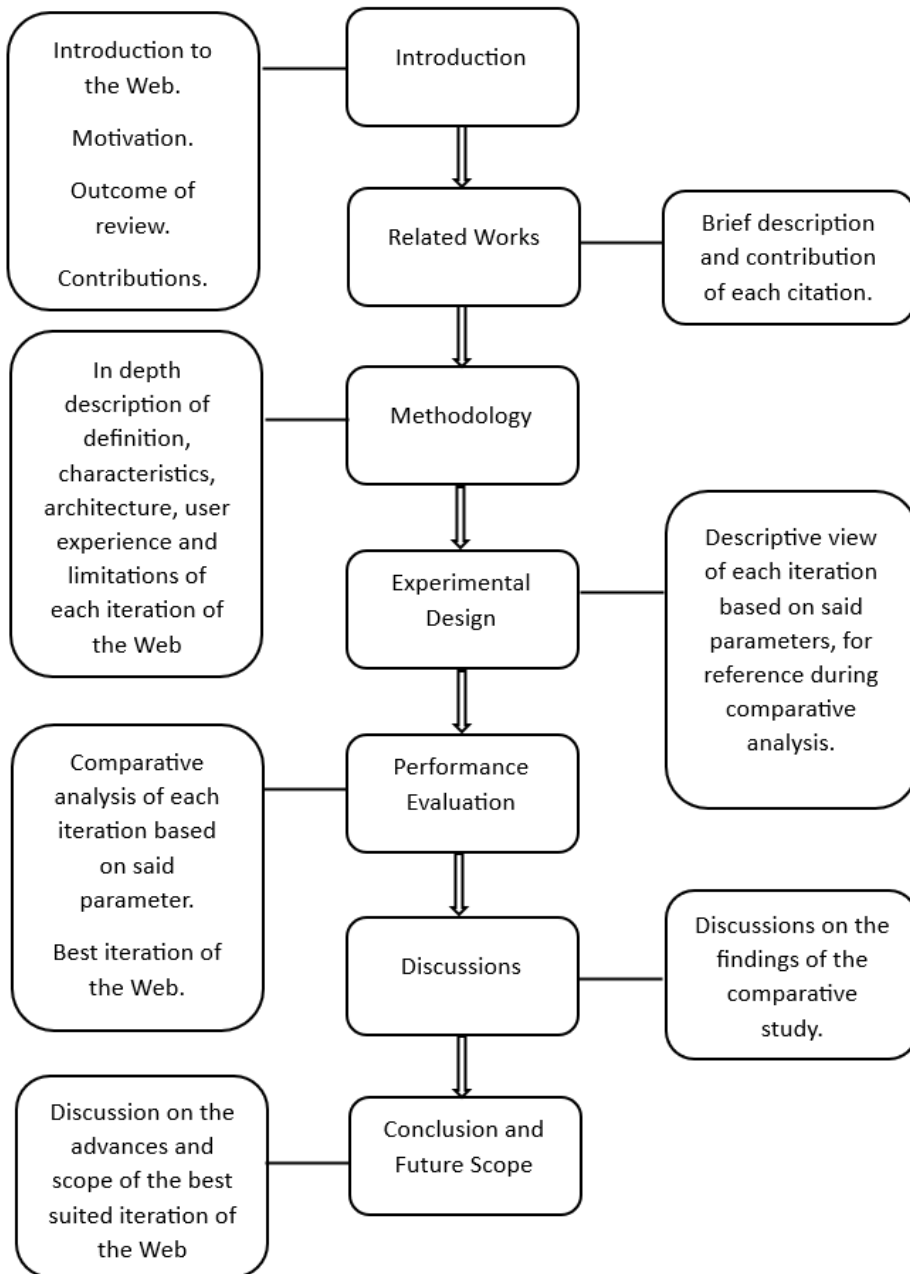
study and review presented in this paper. Finally, the review has been concluded by exploring and presenting the reader with areas that have scope for further research. This section of the review paves way for areas that have greater potential for exploration and research. The reader can delve into these domains and build upon the groundwork laid by this review.

1.1 Contributions

- Blockchain technology – The role of blockchain technology in evolution of the web from centralised and static websites to decentralised and user-centric participatory environments has been clearly elucidated in various sections of this article. This helps the reader to understand the pivotal role assumed by blockchain technology and decentralisation in modifying the digital landscape of the web ecosystems.
- Artificial intelligence (AI) – The role of automation in transformation of the web from static web pages to user-centric platforms has been explained clearly in various sections of this review article. Comprehensions on the above notion have been presented to the reader to help them understand the role of AI in evolution of the web.
- Comparative analysis – A descriptive comparative analysis has been made on the various iterations of the web based on certain chosen parameters. The findings of this review have been studied from various aspects and the results have been presented to the reader. This study aids the reader in understanding the evolution of the web.
- User experience and design characteristics – As a pre requisite for the comparative analysis, the reader has been provided with the characteristics and key features of each version of the web. Key aspects such as architecture, user experience, applications, limitations, socio economic impacts and security and privacy features have been discussed in detail. This comprehension aims to aid the reader through the descriptive comparative analysis.
- Social media integration – The pivotal role of communities with user generated content in the evolution of the web has been discussed in this review article. User trends and web applications for the same have been provided to help the reader gain a better understanding of this subject area. This helps the reader to gain a better grasp of the key influences that led to the transformation of the web.

1.2 Outline of the review

Figure 1 Outline of the work



2 Related works

Berners-Lee et al. (1999) provided insights into the origins of the World Wide Web and its foundational principles in his book 'weaving the web: the original design and ultimate destiny of the World Wide Web'. In this book, he reflects on the evolution of his invention of the Web where he emphasises that the initial vision of the web was to create a decentralised and open platform for information sharing.

O'Reilly (2005) article coined the term 'Web 2.0' and elucidates on the transformation of static web pages into interactive platforms that enable user-generated content, collaboration, and social networking. It introduced the concepts of user participation, collective dependence, and the power of data in the emerging web landscape.

Buterin (2015) explored the scope of blockchain technology and its impact on various industries in their book. This book discusses the principles of decentralisation, transparency, and trust that underpin blockchain systems and how they can transform economic and social structures. Its main subject revolved around the mutation of money and the business world.

Tapscott and Tapscott (2016) introduced the concept of Ethereum blockchain platform and smart contracts via the Ethereum white paper. It outlines the vision of a decentralised computing platform that enables the creation of decentralised applications (DApps) and programmable digital assets. Overall, they described this as a 'next-generation smart contract and decentralised application platform'.

P2P Foundations (P2P Foundations) authored a book titled '*The Business Blockchain*' that explores the business implications of blockchain technology. It discusses the unknown potential use cases of blockchain technology other than cryptocurrencies or supply chain management. This paper presents to us other uses of blockchain technology such as identity verification, and financial services. It also examines the challenges and opportunities of integrating blockchain into existing business models.

Mougayar (2016) put forward a comprehensive study which analyses the global landscape of blockchain technology adoption. It examines the key drivers, challenges, and trends in different sectors, providing insights into the current state of blockchain and potential future developments.

Söllner and Leimeister (2016) discussed the ethical implications of Web 2.0 technologies, focusing on issues such as privacy, surveillance, data ownership, and algorithmic biases. It explores the responsibilities of technology developers and policymakers in addressing these ethical concerns.

The research put forth by Hileman and Rauchs (2017) examines the characteristics and implications of Web 3.0 and decentralised systems. It discusses the potential benefits of decentralisation in areas such as data ownership, privacy, security, and trust, while also highlighting challenges related to governance and scalability.

In 2017, Kshetri (2017) published a magazine article where the importance of blockchain technology with respect to the security and privacy of internet of things (IoT) was discussed. This article emphasises that the centralised cloud servers of the IoT ecosystem, majorly rely on blockchain technology and thus, this technology may also contribute towards the IoT ecosystem's privacy and security. By using blockchain technology, we may also be able to contain the incident after the breach as well.

The evolution of Web 3.0 was majorly possible due to the invention and application of blockchain technology in the internet. Blockchain technology operates this underlying

economic market of the Web using algorithms that can eliminate the possibilities of fraud or risk (Swan, 2015). This helps to constitute all kinds of human activity when it comes to finance and economic markets.

One of the major inconveniences of managing a smart home comes from the issue of energy saving household. Intelligent algorithms have been developed using blockchain technology to help achieve the same. Many IoT platforms and ecosystems using this technology. The interrelatedness of the third iteration of the Web with this proposed system has been elaborated in this article (Li et al., 2017a).

Digital payment systems have completely changed the face of the online economic layer of the internet (Amalia, 2016). Algorithms developed using blockchain technology have decreased the amount of fraud and risk involved in the process of online payments. Apart from the Web, these processes have also been extended to mobile applications. Since its discovery, blockchain technology has shown promising applications in various fields, ranging from smart contracts to cryptocurrency to online payment systems (Li et al., 2017b). Although its ecosystem is yet to be studied and understood fully, its applications are spreading through various fields.

The reference work proposed by Ritzer (2019) claims that the sociology of our culture and society has direct and indirect impact on the societal and economic implications of technology.

This article reviews the investigation of security policies on social networking sites, taking Facebook as the prime example (Grimmelmann, 2008). It elucidates to the reader, why and how certain security policies fail and the steps to be taken thereafter to prevent the breach of privacy of the user. The dynamics of a typical social media platform have been clearly explained taking Facebook as the example, to help the reader understand how security and privacy policies work.

The practice of ethical consumption has seen to be increasing rapidly in North America and Europe, as consumers are using this practice to call out the unethical companies. Consumers are using this approach to call out the unfair trade practices followed in their countries. This research puts forward the relationship between economy and society in the context of ethical consumerism (Carrier and Luetchford, 2012).

With its ever-growing popularity, blockchain has reached various fields of technology (Li et al., 2017b). Consequently, it has created a global hype. Notheisein et al. (2017) have conducted research to understand the blockchain-based markets. Based on this research a blockchain market engineering framework has been proposed to understand the role of blockchain technology in information systems literature.

This research explores the relation between AI and the most recent technological development of social media with reference to domain and methodology (Zeng et al., 2011). Data transfers in social media and interconnected to the process of consumption and circulation of information.

The increasing development in the field of Web 3.0 and blockchain technology has led to the extensive use of metaverse (Chen et al., 2022). But the serious lacking of regulations in these technologies has also had its influence on the metaverse. The future scope and advances of metaverse lie in the intelligent usage of blockchain (Doe et al., 2023). The neurally connected nature of metaverse needs strict yet dynamic security and privacy policies to safeguard its users from crimes, scams or exploitations. This research has broadly studied all types of financial crimes, by dividing them into three types of issues (Wu et al., 2022).

The centralised nature of existing technologies makes room for financial crimes. Hence it is important for us to understand how the decentralised nature of Web 3.0 makes it easy for us to manoeuvre the digital finance and economy. The applications and challenges of Web 3.0 put forward by Chen et al. (2022) annotate the reader on the various ways in which Web 3.0 can be integrated with the digital economy. Quin et al. (2023) proposed a five-layer intelligent architecture, which helps reform product relations with the industry organisations.

As decentralised autonomous organisations (DAOs) are built on Web 3 and blockchain technologies, they have the power to completely disrupt and replace the existing financial and economic intervenors. Though having such potential, it is yet to be used fully by the society as it is not regulated. The complete potential of this technology is yet to be discovered and hence we may not know the threats it possesses. This research highlights all the issues and potential limitations associated with DAOs (Chotkan et al., 2022).

The increase in usage of social machines has led to the development of existing technologies and given rise to newer technologies. The evolution of Web 3.0 from Web 2.0 is one such phenomena (Brito et al., 2020). The research conducted by Brito et al. (2020) studies the development of both software and human behaviour with reference to the evolution of social machines.

The evolution of technology has led to increase in usage of mobile applications. This has opened-up new horizons. However, the conversion of existing web applications to mobile applications using current technologies is not effective. Cajas et al. (2020) conducted a systematic literature review on the methods that transform Web 1.0 technologies into mobile applications.

This paper introduces a framework designed to automate and decentralise the creation and auditing of a robust, secure blockchain-based federated identity within a marketplace (ElGayyar et al., 2020).

Blockchain proved and emerged as the foundational and most suitable technology to manage bitcoin. But blockchain has various other uses beyond bitcoin and the same have been explored in a concise manner in this paper (Veeramani and Jaganathan, 2019).

The increasing number of registered and unregistered users pose a great challenge to the web service. This study proposes an architecture to address the same (Canturk and Karagoz, 2011).

The increase in popularity of social media in the society has a clear relationship with the level of isolation pertaining in the society. This engagement was further studied in the article written by Quinn et al. (2013). The results of this paper are a quantified measure of the relationship between interactions and behaviours of the users.

3 Methodology

This section of the review paper presents a detailed explanation of each iteration of the Web. The explanation begins with an elaborated definition followed by supporting characteristics. Following this, the technology is well-explained with reference to its architecture. Furthermore, the user experience of each version of the Web has been explained by quoting examples of its supporting technologies. Each iteration is concluded by explaining its potential limitations, benefits, implications or future scopes. A brief

outline for the above explained format of the descriptive view for each iteration of the Web has been presented in Figure 2.

3.1 Web 1.0: the static web

3.1.1 Definition and characteristics

The following section presents the reader with the definition and key characteristics of Web 1.0. Understanding the foundational aspects of Web 1.0 is essential for comprehending its limitations and the subsequent developments that led to the emergence of Web 2.0 and Web 3.0. Web 1.0 can be defined as the first generation of the World Wide Web, which emerged in the early 1990s (Berners-Lee et al., 1999). It primarily involved the dissemination of static information through websites that acted as digital brochures or catalogues. The primary focus of Web 1.0 was information retrieval, where users accessed web pages to consume content without active participation or contribution. The characteristics of Web 1.0 include:

- **Static content:** Web 1.0 mainly consisted of static web pages that were characterised by hypertext markup language (HTML) and limited multimedia elements. These websites were predominantly text-based and lacked dynamic or interactive features.
- **One-way communication:** Web 1.0 followed a top-down communication model, with information flowing from the content creator to the end-user. It lacked mechanisms for user feedback, collaboration or active participation.
- **Limited user interaction:** Users had limited interactivity with websites, primarily through basic hyperlink navigation. There were no interactive forms, real-time updates or personalised experiences. The web experience was primarily static, where users consumed information rather than actively engaging with it.
- **Centralised content creation:** Content creation in Web 1.0 was primarily controlled by webmasters and organisations. Individuals had limited opportunities to contribute or create content independently. Websites were mainly created and updated by technical experts, resulting in a centralised approach to content production.
- **Lack of social media and user-generated content:** Social media is a form of user-generated content, which was scarcely present in Web 1.0. There were no mechanisms for users to create profiles, share content, or engage in online communities. This version of the web was primarily an information resource rather than a platform for social interaction.
- **Limited personalisation:** Web 1.0 lacked personalisation features tailored to individual user preferences. Websites provided the same static content to all users without customisation based on their interests or behaviours.
- **Limited connectivity and bandwidth:** Internet connectivity during the Web 1.0 era was slower and less pervasive compared to subsequent generations. Bandwidth limitations restricted the inclusion of rich media elements and real-time interactive features.

While Web 1.0 initially democratised access to information, its limitations became apparent as the internet evolved. With the advent of Web 2.0, characterised by increased

interactivity, user-generated content, and social media platforms, the internet landscape shifted towards greater user engagement and participation. However, it is essential to acknowledge that the progression from Web 1.0 to Web 2.0 was predominantly driven by corporate interests and therefore leading to concerns regarding data ownership and privacy.

Figure 3 depicts the characteristics of Web 1.0. Despite its restrictions, Web 1.0 played a pivotal role in establishing the foundation for subsequent web generations. It laid the groundwork for information dissemination, web design principles, and the progress of early internet technologies. The emergence of Web 2.0 marked a significant shift in user participation, collaboration, and dynamic web experiences, building upon the static nature of Web 1.0 (O'Reilly, 2005). In conclusion, Web 1.0 can be characterised as the early stage of the World Wide Web, where the emphasis was primarily on delivering static content to users (Berners-Lee et al., 1999). It had limited interactivity, static UX and centralised content creation. Websites in Web 1.0 were primarily used to provide information and lacked mechanisms for user participation and collaboration. The focus was on delivering information rather than on creating content for consumers. However, subsequent iterations of the web, namely Web 2.0 and Web 3.0, addressed the limitations of Web 1.0 and brought about significant advancements in web technology and UX. Web 2.0 introduced a more communal and participatory web environment. It let users actively generate and share content through platforms such as social media, blogs, and wikis. Web 2.0 fostered user-generated content, social interactions and collaboration, transforming the web into a dynamic and interconnected ecosystem.

Web 3.0, also known as the Semantic Web, took the evolution further by incorporating intelligent and context-aware features. It aimed to provide personalised and meaningful experiences by leveraging technologies such as machine learning (ML) and generative AI to semantic web standards (Canturk et al., 2011). Web 3.0 focuses on data integration, interoperability, and the ability to understand and process information in a more intelligent and automated manner. Web 2.0 and Web 3.0 have enabled new forms of communication (Söllner and Leimeister, 2016), collaboration, and innovation on the web (O'Reilly, 2005). They have given rise to social networks, online communities, e-commerce platforms, and various interactive web applications. The shift from Web 1.0 to Web 2.0 and Web 3.0 reflects the evolution of the web from a static information delivery system to a dynamic and participatory medium that empowers users to actively engage, create, and connect with others. In summary, while Web 1.0 laid the starting point for the web as we know it today, subsequent iterations such as Web 2.0 and Web 3.0 have brought about significant advancements in terms of interactivity, user participation, and intelligent web experiences. These iterations have transformed the web into a dynamic and interconnected ecosystem where users actively contribute, collaborate, and create meaningful interactions.

3.1.2 Technology and architecture

Web 1.0, the first generation of the World Wide Web, introduced several foundational technologies and architectural principles that laid the groundwork for subsequent web generations. Understanding the technological aspects and architectural characteristics of Web 1.0 is crucial for comprehending the advancements brought about by Web 2.0 and Web 3.0.

Technologies of Web 1.0 include:

- **HTML:** HTML is the fundamental markup language of the web, providing the structure and layout for web pages in Web 1.0. It allowed content creators to define the structure of documents, including headings, paragraphs, links, and images.
- **Hypertext transfer protocol (HTTP):** It refers to the protocol used for transmitting hypertext over the internet. Browsers and web servers communicate using HTTP to generate and respond to web pages in Web 1.0. HTTP facilitated the retrieval and display of static web content.
- **Uniform resource locators (URLs):** URLs provide a standardised way to address and locate resources on the web. They allowed users to access specific web pages or resources by specifying their unique URL in the browser's address bar.
- **Web servers and web browsers:** Web servers hosted web content and responded to HTTP requests from web browsers. Web browsers, such as netscape navigator and internet explorer, rendered HTML documents received from web servers, allowing users to view web pages.

The architecture of Web 1.0 includes:

- **Client-server model:** Web 1.0 operated on a client-server model, where web browsers acted as clients and web servers served as central repositories of web content. Clients (web browsers) made requests to servers (web servers) using HTTP, and servers responded by delivering static web pages to the clients.
- **Static web pages:** Web 1.0 architecture predominantly consisted of static web pages, where content was pre-authored and stored on web servers. These static pages were delivered to clients upon request without the ability to dynamically generate content based on user inputs or real-time data.
- **Statelessness:** Web 1.0 followed a stateless communication model, where web servers did not maintain information about the state of client interactions. Each HTTP request was independent and did not retain any contextual information from previous requests, resulting in limited interactivity and personalisation.
- **Server-side processing:** Web 1.0 relied heavily on server-side processing, where the web servers handled the processing and generation of web content. Clients (web browsers) had minimal processing capabilities and were primarily responsible for rendering and displaying the received HTML content.

A simple architectural model of Web 1.0 has been illustrated in Figure 4. The technology and architecture of Web 1.0 established the foundations for web development and paved the way for subsequent advancements. However, the static nature of Web 1.0 and its reliance on server-side processing and limited interactivity led to the need for a more dynamic and participatory web experience, which was addressed by the subsequent generations, Web 2.0 and Web 3.0. In conclusion, Web 1.0 was built on foundational technologies such as HTML, HTTP, URLs, and the client-server model. It relied on static web pages delivered from servers to clients, with limited interactivity and user engagement. The architecture of Web 1.0 was primarily characterised by statelessness, where each request from the client was treated independently without any memory of previous interactions. Server-side processing was responsible for generating and delivering web pages to the client, while the client's role was mostly in consuming the

information presented. However, the advancements in technology and architecture in subsequent web generations brought about significant changes in the way users interact with web content. Web 2.0, for example, introduced a shift towards more dynamic and interactive experiences. It embraced technologies such as JavaScript, AJAX, and rich internet applications (RIAs) to enable real-time updates, asynchronous communication, and enhanced user interfaces (UI) (O'Reilly, 2005). The introduction of web-based platforms and social media sites allowed users to actively contribute, share, and collaborate, mutating the web into a participatory environment.

Web 3.0 takes this evolution further by incorporating intelligent and decentralised elements. It provides maximum advantage to technologies such as machine learning, semantic web, generative AI and blockchain to provide more personalised, context-aware, and secure experiences. Web 3.0 aims to enable data interoperability, DApps, and user control over personal data, emphasising privacy, security, and trust. The architecture of Web 3.0 moves away from centralised servers towards peer-to-peer networks, where data and services are distributed across a decentralised ecosystem. These advancements in technology and architecture have had transformative effects on the web, allowing for more engaging, interactive, and personalised UX. Web 2.0 and Web 3.0 have shifted the focus from meekly consuming content to engagingly generating and sharing content. The architecture of Web 2.0 and Web 3.0 enables users to contribute, create, and shape the web ecosystem through user-generated content, social interactions, and DApps. In summary, the architecture of Web 1.0 relied on static web pages and the client-server model, providing limited interactivity. Subsequent web generations, such as Web 2.0 and Web 3.0, introduced advancements in technology and architecture that enabled more dynamic, interactive, and intelligent web experiences. These developments have transformed the web into a participatory, user-driven ecosystem, with Web 3.0 emphasising decentralisation and user control over data.

3.1.3 User experience

The user experience (UX) in Web 1.0 was characterised by limited interactivity. Users primarily accessed web pages as informational resources, and their engagement was mainly through browsing and reading. The following section explores the key features of user experience in Web 1.0:

- **Limited interactivity:** In Web 1.0, user interactions were primarily restricted to using hyperlinks and interacting with basic web forms. The web pages were static, providing little opportunity for users to actively engage with the content or contribute their own input. User interactivity was restricted to clicking links to navigate to different pages.
- **Information retrieval:** Web 1.0 focused on information retrieval, where users accessed web pages to find specific content or gather information. The user experience revolved around searching for and consuming the information presented on the static web pages. There were no personalised recommendations or intelligent filtering mechanisms to enhance the user's experience.
- **Limited personalisation:** Personalisation features were virtually non-existent in Web 1.0. Websites provided the same static content to all users, without customising the

experience based on individual preferences, behaviour or location. The lack of personalisation limited the relevance and tailored nature of the user experience.

- **Minimal user control:** Users had limited control over the content they encountered in Web 1.0. The content was predetermined and delivered by webmasters or organisations. Users had no means to customise or modify the content according to their preferences. They had to rely on the information provided by website owners.
- **Lack of multimedia:** Web 1.0 had limited support for multimedia elements such as images, audio, and video. The user experience primarily revolved around text-based content, with minimal visual or interactive elements. This limitation constrained the richness and diversity of the user experience.
- **Limited feedback and collaboration:** Users had limited means to provide feedback or engage in collaborative activities within Web 1.0. There were no comment sections, discussion forums, or social media platforms for users to interact with website owners or other users. Collaboration and user-generated content were not integral parts of the user experience.

In Web 1.0, the user experience was primarily focused on information retrieval. Users would access static web pages that were designed and curated by content providers. The interaction was limited to browsing through the pages, clicking on hyperlinks to navigate between different pages, and consuming the information presented. The content was typically delivered in a one-way communication flow, where the user played the role in consuming the content. However, with the advent of Web 2.0, the user experience underwent a significant transformation. Web 2.0 introduced interactive elements and user-driven content creation. Users were no longer limited to content consumption; they became active participants in the web ecosystem. Social media platforms, blogging platforms, and online communities emerged, enabling users to create and share their content, express their opinions, and engage in discussions with others. This shift towards user-generated content and social interactions gave users a sense of ownership and empowerment, enhancing their overall web experience. Web 3.0 further expanded on the user experience by incorporating personalisation and interactivity. With the consumption of technologies like AI assistants and ML, Web 3.0 can analyse user preferences, behaviours, and context to deliver personalised content and recommendations. Users can have tailored experiences based on their interests, location, and previous interactions. The introduction of intelligent assistants and chatbots also allows for more interactive and conversational interactions with web applications and services.

Web 2.0 and Web 3.0 have also brought about increased interactivity and responsiveness in UI. RIAs and advancements in front-end technologies have enabled more dynamic and interactive web experiences (O'Reilly, 2005). Users can engage with web applications in real-time, perform actions without page reloads, and receive instant feedback. The overall user experience has become more seamless, engaging, and interactive. Furthermore, Web 2.0 and Web 3.0 have fostered a communal feeling and collaborative spirit. Users can connect with others, share ideas, collaborate on projects, and participate in online discussions. The social aspect of the web has enriched the user experience by enabling social interactions, collective dependence, and crowd-sourced knowledge. In summary, while the user experience in Web 1.0 was limited to information retrieval and content consumption, subsequent web generations, particularly Web 2.0 and Web 3.0, have introduced transformative changes. Users now

have opportunities for active participation, content creation, personalisation, social interactions, and collaboration. The web experience has become more interactive, personalised, and community-oriented, enhancing user engagement and empowerment.

3.1.4 Implications and limitations

Web 1.0, with its static web pages and limited user interactivity, had significant implications and inherent limitations that shaped the subsequent developments in web technology. Understanding these implications and limitations provides valuable insights into the need for and the advancements brought about by Web 2.0 and Web 3.0. The following section examines the implications and limitations of Web 1.0 in detail:

Implications of Web 1.0:

- **Information accessibility:** Web 1.0 significantly improved information accessibility by providing a platform for publishing and disseminating content globally. It democratised access to knowledge and empowered individuals to access information from various sources.
- **Digital presence:** Web 1.0 allowed businesses, organisations, and individuals to establish a digital presence by creating websites. This presence enabled them to showcase products, services, and expertise to a global audience, expanding opportunities for communication and collaboration.
- **Global connectivity:** Web 1.0 fostered global connectivity, connecting individuals, communities, and organisations across geographical boundaries. It facilitated communication and collaboration on a scale never seen before, opening up new avenues for international cooperation and exchange of ideas.
- **Information sharing:** Web 1.0 enabled the sharing of information and resources, breaking down barriers to knowledge dissemination. It facilitated the growth of online libraries, educational platforms, and digital repositories, making information more accessible to a wider audience.

Limitations of Web 1.0:

- **Limited user participation:** Web 1.0 lacked mechanisms for user participation and collaboration. Users were merely consumers of information, unable to contribute their own content or actively engage with web pages. This limitation restricted the potential for collective dependence and user-driven innovation.
- **Lack of dynamic content:** Web 1.0 websites primarily consisted of static content, providing little scope for real-time updates or dynamic experiences. The lack of dynamic content limited the relevance, freshness, and interactive nature of the web.
- **Centralised content creation:** Web 1.0 websites were predominantly created and updated by technical experts or webmasters. Individuals had limited opportunities to create and share their own content independently, leading to a centralised approach to content production.
- **Limited interactivity:** Web 1.0 offered limited interactivity, primarily limited to hyperlink navigation and basic web forms. Users had minimal control over the

content they encountered and lacked opportunities for personalised experiences or tailored recommendations.

- Lack of user-generated content: Web 1.0 did not provide mechanisms for user-generated content. Social media platforms, collaborative editing tools, and user-driven communities were absent, limiting opportunities for user-generated creativity and knowledge sharing.
- Lack of personalisation: Web 1.0 websites provided the same static content to all users without customisation based on individual preferences or behaviour. The lack of personalisation limited the relevance and tailored nature of the user experience.
- Limited multimedia support: Web 1.0 had limited support for multimedia elements such as images, audio, and video. The user experience was primarily text-based, with minimal visual or interactive elements.

Understanding the aforementioned implications and limitations of Web 1.0 led to the development of subsequent web generations, such as Web 2.0 and Web 3.0, which aimed to address these limitations and enhance the user experience through increased interactivity, user participation, dynamic content, personalisation, and the integration of multimedia elements. In conclusion, Web 1.0 had a great effect on various aspects of society and technology (Ritzer, 2019). It revolutionised the way information was accessed and shared, enabling global connectivity and the democratisation of knowledge. Web 2.0 empowered users to actively generate and collaborate using content on social media, blogs, wikis, and other collaborative tools (O'Reilly, 2005). It fostered user-generated content, social interactions, and collective dependence, transforming the web into a more engaging and user-centric medium. Web 3.0 leverages technologies such as AI assistants, ML, semantic web, and blockchain (Tapscott and Tapscott, 2016) to enable more intelligent, autonomous, and secure interactions on the web. The applications of Web 2.0 and Web 3.0 are significant. These iterations have opened up new avenues for communication (Söllner and Leimeister, 2016), collaboration, creativity and innovation. The ability to target specific user segments, harness user-generated content, and leverage data-driven insights has revolutionised marketing and advertising practices (Notheisen et al., 2017). Issues such as information overload, security concerns, privacy risks, digital divide, and ethical considerations need to be pointed out to ensure the responsible and inclusive advancement of the web (Quinn et al., 2013). Table 3 shows the key differences between limitations of each iteration of the Web.

Before advancing to the next iteration of the web, it is essential for us to comprehend the term API as we will frequently be using it in our subsequent discussions. API refers to Application programming interface. It is important to note that all web services are functional using APIs but not all APIs constitute web services. APIs are of many types and they are used to build the style of communication with the web service. Few of the commonly used APIs in web services are representational state transfer (REST APIs), simple object access protocol (SOAP APIs), GraphQL APIs and JSON-RPC and XML-RPC APIs. APIs have various functions such as data retrieval, data storage, data transfer and process, error handling and authentication. Thus, all its functions collectively enable a seamless user experience. There is no standard architecture pertaining to APIs as each one differs in its design. However, upon inspecting the documentation provided by the API provider, we can learn about the components of its architecture.

3.2 *Web 2.0: the social web*

3.2.1 *Definition and characteristics*

Web 2.0, also known as the ‘social web’ or the ‘read/write web,’ presents a significant shift in the evolution of the World Wide Web (O’Reilly, 2005). It introduced a new paradigm of user participation, collaboration, and interactive experiences. This section of the paper will explore the definition and key characteristics of Web 2.0:

Definitions of Web 2.0

- Web 2.0, as a second iteration of the World Wide Web, presents a significant shift in the way the web is used and experienced. It was developed in the early 2000s and introduced a new paradigm of web interactions that emphasised user participation, social interaction, and user-generated content. Unlike the static communication of Web 1.0, Web 2.0 fostered dynamic, interactive, and user-centric web experiences.
- One of the key characteristics of Web 2.0 is the emphasis on user participation. Web 2.0 platforms provide users with the ability to actively contribute, create, and share content. Social media platforms, blogs, wikis, and other collaborative tools allow users to publish their thoughts, opinions, and creations for others to access and engage with. This shift towards user-generated content has democratised the web, giving individuals the power to have their voices heard and participate in online communities.
- Social interaction is another hallmark of Web 2.0. Platforms and features that facilitate social connections, such as commenting, liking, sharing and following, have become an integral part of the web experience. Users can engage in discussions, share content with others, and build virtual networks. This social aspect has mutated the web into a more interconnected and communal space, where users can connect with like-minded individuals, form relationships, and collaborate on projects.
- Web 2.0 also brought about a higher level of interactivity compared to its predecessor. RIAs and advancements in front-end technologies enabled more dynamic and responsive web interfaces. Websites became more than just static pages; they transformed into interactive applications that provided real-time updates, personalised experiences, and seamless user interactions. The introduction of Asynchronous JavaScript and XML (AJAX) enabled asynchronous communication between the client and server, allowing for smoother and more interactive web experiences (Söllner and Leimeister, 2016).
- Moreover, Web 2.0 emphasised the idea of the ‘long tail’ in content distribution. It enabled niche interests and specialised topics to flourish by providing platforms for targeted communities. This allowed users to discover and consume content that was specifically tailored to their interests, rather than being limited to mainstream and mass-produced content.
- Overall, Web 2.0 revolutionised the web by shifting the focus from mere information retrieval to active user participation, social interaction, and content generated by users. It transformed the web into a dynamic, collaborative, and personalised ecosystem. The emergence of Web 2.0 has had a profound impact on various

industries, including media, marketing, e-commerce, education and entertainment, by enabling new forms of communication, engagement, and business models.

Characteristics of Web 2.0:

- **User participation:** Web 2.0 places a strong emphasis on user participation, enabling users to actively engage with web content and contribute their own content. Users can create, publish, and share content, fostering a collaborative and participatory environment.
- **User-generated content:** Web 2.0 platforms encourage and facilitate user-generated content. Social media platforms, blogs, wikis, and video platforms allow users to create and publish unique text, images, videos, and other forms of media. This user-generated content enriches the web and drives community engagement.
- **Social interaction and networking:** Web 2.0 introduced social networking features, enabling users to connect with others, form online communities, and engage in social interactions. Social media platforms, discussion forums, and messaging applications facilitate communication, sharing, and collaboration among users.
- **Dynamic and interactive experiences:** Web 2.0 offers dynamic and interactive web experiences. Web pages are no longer static; they can be updated in real-time, providing fresh and current information. AJAX technology enables seamless and responsive UI, allowing for dynamic content loading and interactive features.
- **Communal intelligence:** Web 2.0 utilises the collective dependence of users. Collaborative platforms and crowd-sourced knowledge repositories, such as wikis and question-and-answer platforms, leverage the wisdom of the crowd to accumulate and refine information. User ratings, reviews, and recommendations provide valuable insights and influence decision-making processes.
- **Personalisation and customisation:** Web 2.0 platforms aim to personalise UX by tailoring content and recommendations based on user preferences, behaviour, and social connections. Algorithms and ML techniques analyse user data to provide personalised recommendations and targeted advertisements.
- **Rich media integration:** Web 2.0 incorporates rich media elements. Platforms like YouTube, Flickr, and SoundCloud enable the sharing and consumption of multimedia content.
- **Web APIs and Mashups:** Web 2.0 promotes the use of web application programming interfaces (APIs) that enable developers to access and encrypt data from different platforms, creating innovative and customised applications. Mashups, which combine data and functionality from multiple sources, enable the development of new services and functionalities.

The key attributes of Web 2.0 have been depicted in Figure 5. Web 2.0 represents the significant shift in the web landscape, transforming the internet from a static information resource into an interactive and participatory platform. Its characteristics, such as user participation, user-generated content, social interaction, dynamic experiences, and personalisation, have revolutionised the way people communicate, collaborate, and encrypt information available on the browser. Overall, Web 2.0 sets the stage for the

subsequent evolution of the web, leading to the emergence of Web 3.0, which further expands on these characteristics and introduces new concepts.

3.2.2 *Technology and architecture*

Web 2.0 introduced new technologies and architectural principles that enabled the dynamic, interactive, and collaborative experiences associated with this generation of the web. The following section explores the technological and architectural aspects of Web 2.0:

The technologies of Web 2.0:

- **AJAX:** This enables dynamic updates of web content without requiring a full page reload. AJAX utilises JavaScript and XML (or JSON) to retrieve and display data, enhancing the responsiveness and interactivity of web applications (O'Reilly, 2005).
- **Web services and APIs:** Web 2.0 promotes the use of web browsers and APIs and functionality between different applications. Web APIs provides a standardised way for developers to access and integrate data from various platforms, enabling the development of mashups and innovative applications.
- **Rich media technologies:** Web 2.0 introduced technologies to support rich media integration, including images, audio, and video. Technologies like Adobe Flash (now transitioning to HTML5) allowed for interactive multimedia content, while codecs and streaming protocols enhanced the delivery and playback of audio and video files on the web.
- **Syndication and feeds:** Syndication formats became popular with the emergence of Web 2.0. These technologies enable user subscription to website content and enables them to receive the same in a standardised feed format. RSS readers and aggregators allow users to access and manage content from multiple sources in one place.

The Architecture of Web 2.0:

- **Service-oriented architecture (SOA):** Web 2.0 applications often adopt a SOA, where functionality is provided as services that can be accessed and integrated by other applications. This modular approach allows for greater flexibility, scalability, and interoperability between different systems.
- **Content generated by user platforms:** Web 2.0 platforms emphasise user-generated content, allowing creation of unique content. Social media platforms, blogging platforms, and content management systems provide the infrastructure for users to contribute and interact with content.
- **Collaborative editing:** Web 2.0 introduced collaborative editing platforms such as wikis, where multiple users can collaboratively create and edit content in real-time. This collaborative approach to content creation fosters community participation and collective dependence.
- **Social networking platforms:** Web 2.0 saw the rise of social networking platforms like Facebook (Grimmelmann et al., 2008), LinkedIn, and Twitter. These platforms enable users to connect, communicate, and share content with others, forming online communities and facilitating social interactions.

- Web application development frameworks: Web 2.0 facilitated the development of web applications through frameworks like Ruby on Rails, Django, and ASP.NET MVC. These frameworks provide tools and libraries that simplify the development process, enabling developers to create dynamic and interactive web applications more efficiently.
- Cloud computing: Web 2.0 applications often leverage cloud computing technologies to provide scalable and on-demand computing resources. Cloud platforms enable the hosting, storage, and processing of large volumes of data, supporting the scalability and availability requirements of Web 2.0 applications.

Figure 6. depicts a simple architectural model of Web 2.0. AJAX enabled asynchronous communication between the client and server, allowing for real-time updates without full page refreshes. Web services facilitated data and functionality exchange between different systems. Rich media technologies enhanced the presentation of multimedia content. Syndication formats like RSS and Atom allowed users to subscribe to updates from various sources (O'Reilly, 2005). Collaborative editing platforms fostered collaboration and crowd-sourced content creation. Overall, these advancements transformed the web into a more engaging, interconnected, and user-centric environment.

3.2.3 User experience

The user experience (UX) in Web 2.0 is designed to promote active user participation, collaboration, and interactive experiences (O'Reilly, 2005). It emphasises social interaction, personalisation, interactivity, and collaboration. Users were encouraged to actively contribute, create and share content, fostering a sense of ownership and engagement. Social networking features facilitate connections and conversations. Personalisation allows users to customise their experiences, tailoring content to their interests. Interactivity enables users to engage with web pages, comment, rate, and contribute to discussions. Collaboration tools and platforms facilitate collective dependence and crowdsourcing. Seamless integration of web services provides a unified and convenient experience across platforms. Overall, the user experience in Web 2.0 is engaging, user-centric, and interactive. The user experience in Web 2.0 has taken several forms such as:

- Participation of the user: Web 2.0 encourages active user participation, allowing users to contribute their own content, opinions, and feedback. Users can create blog posts, upload videos, share photos, and engage in discussions on social media platforms. This increased participation fosters a sense of ownership, empowerment, and community engagement.
- Community interaction: Web 2.0 platforms prioritise social interaction, enabling users to connect with others, form online communities, and engage in conversations. Social networking platforms, discussion forums, and comment sections facilitate communication, collaboration, and the sharing of ideas among users. Users can follow, like, comment, and share content, fostering social connections and building relationships.
- User-generated content: Users can write blog posts, create videos, contribute to wikis, and share their opinions and expertise. This democratisation of content

creation gives users a sense of agency, creativity, and the opportunity to showcase their talents and interests.

- **Personalisation and customisation:** Web 2.0 platforms offer personalisation features that allow users to customise their experiences based on their preferences, interests, and social connections. Users can customise their profiles, select preferences, and receive personalised recommendations. This personalisation enhances the relevance, engagement, and tailored nature of the user experience.
- **Dynamic and interactive experiences:** Web 2.0 provides dynamic and interactive web experiences, moving away from static content. Users can experience real-time updates, live streaming, interactive media players, and interactive web applications. The use of AJAX technology allows for seamless and responsive UI, providing a smooth and interactive user experience.
- **Collaborative editing and crowdsourcing:** Web 2.0 platforms facilitated collaborative editing and crowdsourcing, where multiple users could contribute to the creation and editing of content. Wikis and collaborative document editors allowed users to collaborate in real-time, harnessing the collective knowledge and expertise of the crowd. This collaboration enhanced the quality, accuracy, and diversity of content.
- **Discovery and recommendation:** Web 2.0 platforms employed algorithms and recommendation systems to help users discover new content, connect with like-minded individuals and explore relevant information. Recommendation engines analysed user behaviour, preferences, and social connections to provide personalised recommendations, enhancing the serendipity and discovery aspect of the user experience.
- **Seamless multi-device experience:** Web 2.0 focused on providing a seamless user experience across different devices and screen sizes. Responsive web designs ensured that websites and applications adapt and optimise their layout and functionality based on the device being used. This enables users to access and interact with content seamlessly, regardless of the device they are using.
- **Gamification and rewards:** Web 2.0 incorporated elements of gamification to enhance user engagement and motivation. Gamification techniques, such as badges, points, leaderboards, and challenges, encouraged users to actively participate, contribute, and achieve goals. This game-like approach fostered a sense of accomplishment, competition, and fun.

The user experience in Web 2.0 is characterised by active participation thereby enabling users to contribute, share, and create their own content. It promotes social interaction, allowing users to connect, communicate, and collaborate with others. User-generated content empowers individuals to shape the web and express their creativity. Personalisation features tailor the web experience to individual preferences, ensuring relevant and personalised content. Interactivity enhances user engagement, enabling users to interact with web pages, express their opinions, and participate in discussions. Collaboration tools facilitate teamwork and knowledge sharing among users. Lastly, the discovery aspect of Web 2.0 enabled web users to explore and uncover new content, resources, and opportunities (O'Reilly, 2005). Together, these elements created a more immersive, dynamic, and socially connected user experience.

3.2.4 Implications and limitations

Web 2.0 brought about significant implications and limitations that shaped the way we interact, share information, and conduct business online. While it revolutionised the web landscape, it also presented certain challenges and considerations. These include the democratisation of information sharing, impact on communication and social interaction, transformation of business models, accessibility and digital divide, data privacy and security concerns, dependence on third-party platforms, and issues related to information overload and filter bubbles. Recognising and addressing these challenges became crucial for the continued development and evolution of the web ecosystem. The implications and limitations of Web 2.0 have been mentioned below:

Implications of Web 2.0:

- **Democratisation of content:** Web 2.0 enabled the democratisation of content creation, allowing individuals and communities to publish and share their ideas, opinions, and creative works. This opened new avenues for expression, creativity, and diverse perspectives, thus leading to democratisation of content.
- **Enhanced collaboration:** Web 2.0 fostered collaboration and collective dependence, as users could contribute, edit, and refine content in real-time. This facilitated collaborative projects, knowledge sharing, and the creation of comprehensive and up-to-date information repositories.
- **Empowered user communities:** Web 2.0 empowered user communities by providing platforms for networking, communication, and activism. Users could form online communities, share experiences, and mobilise for social, political, or cultural causes.
- **Business transformation:** Web 2.0 revolutionised business models, as companies could harness user-generated content, social media marketing. The emergence of online advertising, content monetisation became significant revenue streams.
- **Accessibility and information sharing:** Web 2.0 facilitated the widespread availability of information and knowledge sharing. Users could access a wealth of resources, connect with experts, and contribute to online communities irrespective of their geographical location.

Limitations of Web 2.0:

- **Quality control:** The democratisation of content creation in Web 2.0 raised concerns regarding the accuracy, reliability, and credibility of information. User-generated content may vary in quality, and misinformation or false information can spread rapidly. Ensuring content quality and fact-checking became significant challenges.
- **Privacy and security:** Data breaches or unauthorised access can compromise privacy on social media. Maintaining robust security measures and user data protection became imperative.
- **Information overload:** The abundance of information available through Web 2.0 platforms can lead to information overload and difficulty in finding relevant content. The sheer volume of user-generated content and the need for effective search and filtering mechanisms presented challenges in information organisation and retrieval.

- **Digital divide:** While Web 2.0 expanded access to information and communication, it also highlighted the digital divide. Not everyone had equal access to technology, internet connectivity, and digital literacy, creating disparities in access to opportunities and participation in the digital sphere.
- **Dependence on connectivity and infrastructure:** Web 2.0 experiences rely heavily on internet connectivity and robust infrastructure. Limited access to reliable internet connections, especially in remote areas or developing regions, can hinder the seamless user experience and participation.
- **Information silos and filter bubbles:** Web 2.0 platforms employ algorithms and recommendation systems that can inadvertently create information silos and filter bubbles.
- **Digital exhaust and data ownership:** Web 2.0 platforms collect extensive user data, often referred to as digital exhaust. Concerns about data ownership, control, and the use of personal data for targeted advertising or surveillance emerged as important considerations.

3.3 *Web 3.0: the semantic web*

Web 2.0 introduced significant benefits such as the democratisation of content, enabling users to actively contribute and collaborate. It transformed the business landscape by providing new avenues for entrepreneurship and digital marketing. However, it also presented challenges such as ensuring content quality and credibility, addressing privacy concerns, managing information overload, bridging the digital divide, and dealing with dependencies on technological infrastructure. Recognising and addressing these implications and limitations is essential to navigate the evolving web landscape and meet the diverse needs of users and businesses. Table 3 shows the key differences between limitations of each iteration of the web.

3.3.1 *Definition and characteristics*

Web 3.0 represents the next stage of evolution in the development of the World Wide Web. The evolution of the Web into its various iterations has been depicted in Figure 7.

The following section explores the definition and key characteristics of Web 3.0 in more detail:

- These technologies empower web applications to process and analyse vast amounts of data, derive insights, and provide personalised experiences to users. With AI and ML algorithms, the web becomes more adaptive and capable of understanding user preferences and behaviour, leading to more tailored and relevant content recommendations.
- **Integration of decentralised protocols and blockchain technology.** By integrating blockchain, Web 3.0 aims to decentralise data storage and ownership, enabling individuals to have more control over their personal information (Tapscott and Tapscott, 2016).

- This semantic approach allows for better information retrieval, discovery, and integration across different platforms and applications. It enables the seamless exchange and integration of data from various sources, leading to a more comprehensive and interconnected web experience.
- By leveraging advanced technologies and semantic data integration, it promises to revolutionise information retrieval, personalisation, privacy, and security on the web (Canturk et al., 2011). However, the full realisation of Web 3.0 is still an ongoing process, with ongoing research, development, and adoption needed to fully realise its potential.

Characteristics

Web 3.0 exhibits several key characteristics that differentiate it from its predecessors. These characteristics include:

- Machine readable and semantically enriched data: Web 3.0 focuses on making data machine-readable and semantically enriched, allowing machines to understand and interpret the meaning of information. Web 3.0 enables more precise and context-aware data representation.
- Intelligent and personalised experiences: Web 3.0 aims to provide intelligent and personalised experiences for users. By leveraging AI and ML algorithms, the web can analyse user preferences, behaviours, and contextual information to deliver tailored and relevant content, recommendations, and services. This leads to enhanced user engagement and satisfaction.
- Decentralisation and peer-to-peer networks: The idea of decentralisation, shifting away from centralised control and intermediaries. It embraces blockchain, enabling data and services to be distributed and accessed without relying on a central authority (P2P Foundations). This decentralisation enhances security, privacy and data ownership.
- Interoperability and linked data: Web 3.0 emphasises interoperability and linked data, enabling seamless integration and exchange of information across different platforms and systems. It fosters the development of standardised protocols and APIs that facilitate data sharing, collaboration, and integration of diverse data sources. This interconnectedness enhances the discoverability and accessibility of information.
- Trust, security, and privacy: Web 3.0 places a strong emphasis on trust. Blockchain technology, with its decentralised and immutable nature, enhances data integrity and security. Smart contracts enable automated, transparent, and trust less interactions (Buterin, 2015). Web 3.0 strives to determine how their information is shared and used.
- Web of data and services: Web 3.0 envisions a web of interconnected data and services, where information is linked and can be dynamically accessed and utilised by various applications. APIs, micro-services, and interoperable protocols enable the integration and composition of services, fostering innovation and collaboration among different applications and systems.

- Contextual and ubiquitous computing: Web 3.0 embraces contextual and ubiquitous computing, where web-enabled devices and applications seamlessly interact with the physical environment. It enables intelligent applications to utilise contextual information, such as location, preferences, and sensor data, to provide personalised and location-aware services.
- Immersive experiences: These technologies enable users to interact with digital content in more intuitive and immersive ways, blurring the boundaries.

Web 3.0 represents a significant evolution in the capabilities and possibilities of the web. By leveraging advanced technologies and embracing principles of decentralisation and intelligence.

3.3.2 Technology and architecture

Web 3.0 has introduced new technologies and architectural principles that enabled the development of a more intelligent, decentralised and interconnected web ecosystem (Qin et al., 2023). These technologies and architectural concepts play an important part in shaping the infrastructure and functionality of Web 3.0. The architectural model of Web 3.0 has been depicted in Figure 8. The following section explores the key technologies and architectural aspects of Web 3.0 in more detail:

- Blockchain technology: It enables the creation of distributed ledgers, where data is stored across a network of nodes in a transparent, immutable, and verifiable manner. Blockchain technology ensures data integrity, facilitates trust less interactions (Doe et al., 2023).
- Semantic web technologies: Web 3.0 leverages semantic web technologies to enhance data interoperability and understanding. Resource description framework (RDF), web ontology language (OWL), and SPARQL (a query language for semantic data) enable the representation, linking, and querying of semantically enriched data. These technologies facilitate machine understanding of data, enabling intelligent applications to process and interpret information more effectively.
- AI and ML: AI and ML techniques are integral to Web 3.0, enabling intelligent data analysis, prediction, and personalisation. ML algorithms can process vast amounts of data, extract patterns, and make predictions or recommendations based on user behaviour and preferences. AI technologies such as natural language processing (NLP) enable machines to understand and interact with human language, facilitating more natural and context-aware interactions.
- APIs: APIs play a crucial role in Web 3.0 by enabling interoperability and integration between different applications and services. Open APIs allow developers to access and utilise functionality, data, and services from various sources, fostering collaboration and innovation. APIs also facilitate the development of DApps that interact with blockchain networks and decentralised services (Tapscott and Tapscott, 2016).
- Smart contracts: Smart contracts are self-executing agreements written in code that reside on blockchain platforms. They automatically enforce the terms and conditions of an agreement without the need for intermediaries. Smart contracts enable trustless

and transparent transactions, eliminating the need for traditional legal frameworks in certain scenarios. They enable the development of DApps and the automation of business processes (Buterin, 2015).

- **IoT integration:** Web 3.0 incorporates the integration of IoT devices into the web ecosystem. IoT devices generate massive amounts of data, and by connecting them to the web, this data can be utilised to create intelligent and context-aware applications. Web 3.0 enables seamless communication and interaction between web applications, blockchain networks (Tapscott and Tapscott, 2016), and IoT devices, leading to more connected and intelligent environments.
- **Microservices architecture:** Web 3.0 promotes the use of microservices architecture, where complex applications are built as a collection of small, loosely coupled services. These services can be developed and deployed independently, facilitating scalability, flexibility, and ease of maintenance. Microservices architecture allows for the integration of various components and services, enabling a modular and adaptable web ecosystem.
- **Privacy-enhancing technologies:** Web 3.0 places a strong emphasis on privacy-enhancing technologies to protect user data and ensure confidentiality. Techniques such as zero-knowledge proofs (ZKPs), homomorphic encryption, and differential privacy allow for secure data processing and sharing while preserving individual privacy.

Web 3.0 is built on a combination of several key technologies that collectively shape its characteristics and capabilities. These technologies include blockchain, decentralised networks for data storage, verification, and transactions. By utilising cryptographic techniques and distributed consensus algorithms, blockchain enables the creation of trustless and tamper-proof systems (Tapscott and Tapscott, 2016). It ensures data integrity, immutability and transparency, which are critical for establishing trust in the digital realm. Decentralised networks help in removing the need for central authorities or intermediaries. These networks, such as peer-to-peer networks, enable direct interactions between users, fostering a more decentralised and resilient web ecosystem. They allow for greater user autonomy, data ownership, and control over digital interactions.

Semantic web technologies focus on enhancing the structure and meaning of web data. The use of semantic metadata, ontologies and linked data facilitates better information discovery, integration and reasoning. This semantic layer enables machines to process and analyse data, leading to more personalised and context-aware web experiences. AI and ML technologies bring intelligence and automation to Web 3.0 which give recommendations based on patterns and insights. AI techniques, such as NLP and computer vision, enhance human-like interactions and understanding within the web environment. These technologies enable personalised content recommendations, intelligent search capabilities, and automated decision-making processes. Web 3.0 holds the promise of a more user-centric and privacy-preserving web, where individuals have ownership and sovereignty over their digital lives. However, the full realisation of Web 3.0 requires further research, development, and adoption of these technologies, as well as addressing associated challenges and considerations.

3.3.3 User experience

Web 3.0 focuses on enhancing the user experience by leveraging intelligent technologies, decentralised principles, and personalised services. The following section explores the key aspects of user experience in Web 3.0 in detail:

- **Personalisation and context-awareness:** Web 3.0 emphasises personalised experiences tailored to individual users. By leveraging AI, ML, and data analytics, Web 3.0 applications can analyse user preferences, behaviours, and contextual information to provide relevant and customised content, recommendations, and services (Zeng et al., 2011).
- **Intelligent assistants and chatbots:** Web 3.0 introduces intelligent assistants and chatbots that leverage NLP and AI techniques to interact with users in a conversational manner. These assistants can provide information, perform tasks, and assist users in navigating the web ecosystem. Intelligent assistants enhance the user experience by offering personalised guidance, recommendations, and support, making interactions more intuitive and efficient.
- **Immersive technologies:** These technologies enable users to engage with digital content in more immersive and interactive ways. Immersive experiences enhance engagement, storytelling, and visualisation, providing users with captivating and memorable interactions.
- **Seamless interoperability:** Web 3.0 aims to enhance interoperability between different applications, services, and platforms. Through standardised protocols, APIs, and data formats, Web 3.0 enables seamless integration and data exchange, allowing users to interact with various services without friction. This interoperability simplifies the user experience, as users can access and utilise diverse functionalities and services within the web ecosystem without the need for complex integration efforts.
- **Enhanced security and privacy:** Web 3.0 prioritises security and privacy to protect user data and foster trust in the web ecosystem. Through blockchain technology and decentralised principles it provides transparent and tamper-proof data storage and transactions (Tapscott and Tapscott, 2016). It ensures the confidentiality of user data. By prioritising security and privacy, Web 3.0 enhances user confidence and peace of mind while engaging with online services.
- **User empowerment and data ownership:** Through decentralised principles, users can manage the data, decide how it is shared and used, and potentially monetise their data. User empowerment and data ownership foster trust, transparency, and user-centricity, empowering individuals to actively participate in the web ecosystem.
- **Enhanced collaboration and social interactions:** Web 3.0 fosters enhanced collaboration and social interactions by leveraging decentralised networks and peer-to-peer communication (P2P Foundations). This allows sharing of resources, and participating in decentralised communities and networks. These collaborative features facilitate knowledge sharing, co-creation, and social interactions, enriching the user experience and enabling users to connect with like-minded individuals and communities.

- **Simplified UI:** Web 3.0 promotes simplified UI that prioritise ease of use and intuitive interactions. UI are designed to be responsive, accessible, and visually appealing, providing a seamless and enjoyable user experience across different devices and screen sizes. Clear navigation, minimalistic design, and intuitive controls contribute to a frictionless user experience, ensuring that users can quickly and efficiently accomplish their tasks and goals.

Web 3.0 aims to revolutionise the user experience by delivering personalised, immersive, secure, and empowering interactions. Leveraging intelligent technologies, decentralised principles, and user-centric design, Web 3.0 creates a web ecosystem that caters to individual users' unique needs and preferences. It emphasises personalisation, immersive experiences, security, privacy, empowering user interactions, seamless connectivity, and collaboration. Hence we can engage in meaningful collaborations, and enjoy seamless interactions.

3.3.4 Implications and potential benefits

The emergence of Web 3.0 brings forth significant implications and potential benefits across various domains. The following section explores the implications and potential benefits of Web 3.0 in detail:

- **Decentralisation and trust:** This reduces reliance on central authorities and intermediaries, resulting in a more transparent and trustless environment. Decentralisation fosters trust among users during their digital interactions.
- **Data ownership and privacy:** With decentralised principles and privacy-enhancing technologies, individuals can determine how their data is shared and used, ensuring greater privacy and protection against unauthorised data collection. Users can potentially monetise their data and participate in data marketplaces, creating new opportunities for individuals to benefit from their own information.
- **Enhanced security:** Web 3.0's adoption of blockchain technology and decentralised networks enhances security in various ways. Cryptographic techniques, smart contracts, and consensus mechanisms improve the security of transactions and data storage (Buterin, 2015). The transparent and auditable nature of blockchain technology increases accountability and reduces fraudulent activities.
- **Innovation and interoperability:** With APIs, developers can create modular and interoperable applications that can seamlessly integrate with other components of the web ecosystem. This fosters innovation and collaboration, as developers can leverage existing functionalities and build upon them.
- **Personalised and intelligent experiences:** Web 3.0 leverages AI, ML, and data analytics to provide personalised and intelligent experiences to users. By analysing user data and preferences, applications can deliver tailored content, recommendations, and services. This leads to increased user engagement, satisfaction, and efficiency in finding relevant information and resources (Zeng et al., 2011).
- **Economic opportunities:** Web 3.0 introduced new economic opportunities through various mechanisms. The use of cryptocurrencies and tokenisation enables

innovative business models and new forms of digital assets. Users can participate in decentralised finance (DeFi) platforms, lending and borrowing, and earn rewards through staking and yield farming. Web 3.0 also enables crowdfunding by Buterin (2015) opening new avenues for investment and entrepreneurship.

- **Democratisation of access:** Web 3.0 aims to democratise access to information, services, and opportunities. Decentralised networks and protocols allow users from around the world to access and utilise resources without restrictions. This provides financial services, education, and other essential resources that were previously limited.
- **Disintermediation and cost reduction:** Web 3.0 reduces reliance. This disintermediation can lower costs associated with traditional centralised systems. For example, financial transactions can be conducted directly between parties. Similarly, the elimination of intermediaries in content distribution can enable creators to monetise their work more directly, benefiting from a larger share of the revenue.
- **Civic and social impact:** Web 3.0 has the potential to bring significant civic and social impact (Tapscott and Tapscott, 2016). DApps can facilitate peer-to-peer aid and charity, bypassing bureaucratic hurdles and ensuring efficient distribution of resources in times of crisis.

While Web 3.0 offers promising benefits, it also presents challenges and considerations. These include scalability, energy consumption, regulatory frameworks, and user adoption. Addressing these challenges is crucial for realising the full potential of Web 3.0 and ensuring its responsible and sustainable implementation. Finding solutions for scalability, reducing energy consumption, establishing appropriate regulatory frameworks, promoting user adoption, and enhancing security and trust will be key areas of focus in the development and adoption of Web 3.0.

4 Experimental design and results

This section of the article acts as the basis for the comparative analysis of the review paper. The following section provides descriptive view of each iteration of the web in terms of criterion like scalability, speed, interoperability, security, privacy, decentralisation, trustworthiness, reliability, accessibility, usability, innovation, sustainability, openness, governance and economic empowerment, to make reference to while making the comparative analysis in Section 5. While a detailed description of each iteration of the Web based on the above said parameters has been drawn, a brief description based on added specifications has also been made available in this section, in the form of a tabular data in Table 1. The aforementioned parameters have been chosen in a manner that offers a comprehensive view of the strengths and weaknesses of each iteration of the web, covering technical, user-centric and societal aspects. Figure 9. represents the difference between each iteration of the Web.

4.1 Scalability

Web 3.0 addresses the issue of scalability by implementing various solutions. The scalability improvements ensure that Web 3.0 can handle a significantly higher number

of users and transactions without compromising performance. In Web 3.0, scalability is a key focus area, and various solutions are being implemented to address this challenge. These solutions aim to offload transactions from the main blockchain, reducing the burden on the network and increasing scalability. State channels and side chains are examples of layer 2 scaling solutions that enable off-chain processing of transactions while still leveraging the security of the underlying blockchain. By conducting transactions off-chain and only settling the final outcome on the main blockchain, these solutions improve scalability and reduce transaction fees (Veeramani and Jaganathan, 2019). These consensus algorithms require less computational power compared to traditional proof-of-work (PoW) algorithms, enabling faster transaction processing and higher scalability. By implementing these scalability solutions, Web 3.0 aims to create a more efficient and scalable network that can accommodate the growing demands of DApps, smart contracts, and user interactions (Buterin, 2015). These advancements ensure that Web 3.0 can handle a larger user base and a higher volume of transactions, paving the way for widespread adoption and improved UX in the decentralised web.

4.2 Speed

Web 3.0 aims to enhance website loading times and overall responsiveness. This is achieved through various optimisations, including the use of content delivery networks (CDNs) to deliver website content from geographically distributed servers, reducing latency. Additionally, advancements in web technologies like WebAssembly enable the execution of high-performance code directly in the user's browser, resulting in faster and more efficient processing. The integration of caching mechanisms and data compression techniques further contributes to improved speed and responsiveness, ensuring a seamless user experience. In Web 3.0, optimising website loading times and overall responsiveness is a key objective. Several strategies and technologies are employed to achieve this goal. One approach is the use of CDNs, which are networks of geographically distributed servers. This reduces the latency and improves the speed of content delivery, resulting in faster website loading times. Another technology that contributes to improved performance in Web 3.0 is Web Assembly.

By bypassing the need for interpretation or translation, WebAssembly enables the execution of complex computations and resource-intensive tasks efficiently, resulting in faster and more responsive web applications. Caching mechanisms also play a vital role in enhancing website speed and responsiveness in Web 3.0. Caching involves storing frequently accessed data or resources in a temporary storage location, such as the user's browser or intermediate servers. When a user revisits a website, the cached data can be retrieved quickly, reducing the need to fetch the data from the original source. This significantly improves the loading times of web pages and enhances the overall user experience. Furthermore, data compression techniques are employed to minimise the size of data transferred between servers and clients. Compression algorithms result in faster data transfer and improved website performance. Gzip and Brotli are common compression algorithms used in Web 3.0 to reduce the size of files like HTML, CSS, and JavaScript, optimising the loading times of web pages. By implementing these optimisations, Web 3.0 aims to provide users with faster, more responsive websites. These technologies and strategies contribute to a seamless user experience, reducing wait times and enhancing the overall efficiency of web interactions in the decentralised web.

4.3 Interoperability

Web 3.0 emphasises interoperability between different applications and platforms. It achieves this through open standards and protocols such as the inter planetary file system (IPFS) and the universal data interchange (UDI) format. IPFS corresponds to a peer-to-peer method of storing and sharing hypermedia using a distributed file system. It is designed in such a way that it replaces the conventional centralised model of the Web with a decentralised model that is more transparent, secure and faster. In simple terms it helps to store and share data across the network using a shared file system. Whereas UDI is a globally unique identifier. It helps to identify the data location and transmits the data from that location. UDIs are decentralised, as they can be created and operated by anyone. This protocol helps to gain better control over data and results in an efficient data storage and management system. These technologies enable the exchange and sharing of data across different systems and facilitate seamless integration between DApps. By promoting interoperability, Web 3.0 allows for the efficient utilisation of data and services, fostering collaboration and innovation across the web. In Web 3.0, interoperability is a key focus, enabling seamless communication (Söllner and Leimeister, 2016) and integration between different applications and platforms. Unlike traditional web addressing based on URLs, IPFS uses unique cryptographic hashes to reference and retrieve content. This decentralised approach allows for the efficient distribution and sharing of files across different nodes and systems, ensuring data availability and resilience. By leveraging IPFS, Web 3.0 applications can seamlessly access and exchange files, regardless of their original source or location. Another technology that supports interoperability in Web 3.0 is the UDI format. UDI is a standardised format for representing and exchanging data, ensuring compatibility and interoperability across platforms. By adhering to the UDI format, Web 3.0 applications can easily exchange and interpret data, enabling seamless integration and collaboration. These open standards and protocols foster a collaborative and interconnected web ecosystem in Web 3.0. They enable different applications and platforms to interact, share data, and leverage each other's functionalities, leading to enhanced innovation, efficiency, and UX. The emphasis on interoperability in Web 3.0 encourages the development of a decentralised and open web where users can seamlessly navigate and utilise services from various sources, fostering a more inclusive and dynamic online environment.

4.4 Security

Web 3.0 places a strong focus on security to protect user data and transactions. One of the key security features is decentralised identity management, where users have control over their digital identities without relying on centralised authorities. This ensures that users maintain ownership and control over their personal information. Additionally, the use of cryptographic techniques, such as public-key cryptography, enables secure and tamper-proof communication and transaction verification (Söllner and Leimeister, 2016). Smart contract auditing and formal verification techniques help identify vulnerabilities and ensure the reliability and security of DApps, mitigating the risk of exploits and attacks (Buterin, 2015). Security is indeed a critical aspect of Web 3.0, aiming to provide users with enhanced protection for their data and transactions. Web 3.0 introduces several security features to achieve this goal. Decentralised identity management is a

fundamental principle of Web 3.0. It empowers users with control over their digital identities through decentralised identity systems, such as self-sovereign identity (SSI). In Web 3.0, users can manage and authenticate their identities without relying on centralised authorities or third-party intermediaries.

This ensures that users maintain ownership and control over their personal information, reducing the risks associated with centralised data breaches and unauthorised access. Cryptographic techniques play a crucial role in securing Web 3.0. Public-key cryptography, for instance, enables secure and private communication between users and applications. It ensures that data transmitted over the network is encrypted and can only be decrypted by the intended recipient, protecting sensitive information from unauthorised access or interception. Another security measure in Web 3.0 is the use of smart contracts and DApp auditing. Smart contracts are self-executing contracts with the terms and conditions defined in code. Auditing smart contracts helps identify vulnerabilities and potential security flaws in the code, ensuring that the contracts function as intended and are not susceptible to exploits or attacks. Formal verification techniques, which involve mathematically proving the correctness of code, can be employed to enhance the security and reliability of smart contracts (Buterin, 2015). By incorporating these security features, Web 3.0 aims to create a more trustworthy and resilient web ecosystem. Users have greater control over their data, communication is secured through cryptographic techniques, and DApps undergo auditing to ensure their reliability and robustness. These security measures mitigate the risks associated with centralised vulnerabilities, unauthorised access, and malicious activities, fostering a safer and more secure online environment for users in the era of Web 3.0.

4.5 Privacy

Privacy is indeed a crucial aspect of Web 3.0, aiming to protect user information. Web 3.0 introduces various privacy-enhancing technologies and principles to achieve these goals. SSI selectively disclose information as needed, without revealing unnecessary details. Users can authenticate themselves and access services without relying on centralised authorities or exposing their entire identity, promoting privacy and minimising the collection of personal data. ZKPs are another powerful privacy tool used in Web 3.0. This cryptographic technique enables secure and private interactions, as users can provide proof of knowledge without exposing sensitive details. For example, a user can prove they are above a certain age without disclosing their exact birthdate. Privacy-focused blockchain networks and protocols also contribute to Web 3.0's privacy enhancements. Privacy-enhancing protocols, like zero-knowledge rollups or mixers, help protect transaction data and identities on the blockchain, preventing the correlation of user activities and enhancing privacy. By integrating these privacy-enhancing technologies and principles, Web 3.0 aims to provide users with the freedom to control their personal information and choose the level of privacy they desire. It prioritises the protection of user data, reduces reliance on centralised authorities, and ensures that sensitive information remains confidential. Privacy is a fundamental pillar of Web 3.0, enabling individuals to navigate the digital landscape with confidence, trust, and autonomy.

4.6 *Decentralisation*

Decentralisation is a fundamental aspect of Web 3.0, aiming to reduce reliance on central authorities and create a more equitable and resilient web. Web 3.0 leverages blockchain and distributed ledger technologies (DLT) to decentralise data storage, enabling data to be stored across multiple nodes in a network. This distributed storage model enhances data redundancy and fault tolerance, reducing the risk of single points of failure. By utilising decentralised technology, we create a more democratic and inclusive system. Decentralisation is indeed a central principle of Web 3.0, aiming to transform the web into a more equitable, resilient, and democratic ecosystem. Web 3.0 leverages blockchain and DLT to decentralise various aspects of the web, including data storage, decision-making processes, and governance structures. One of the key elements of decentralisation in Web 3.0 is the decentralised storage of data. Traditional web architectures rely on centralised servers and data centres, which can be vulnerable to single points of failure and data breaches. In Web 3.0, data is stored across multiple nodes in a network, using technologies such as blockchain or distributed file systems like IPFS.

This distributed storage model enhances data redundancy, fault tolerance, and censorship resistance. Decentralisation in Web 3.0 goes beyond data storage. Traditional web models often concentrate decision-making power in the hands of a few central authorities. In contrast, Web 3.0 utilises a decentralised network to enable collective decision-making by network participants. These mechanisms help in the validation and verification of transactions, the creation of new blocks, or the election of block producers. By involving a broader range of participants and distributing decision-making authority, Web 3.0 promotes a more democratic and inclusive system. Furthermore, decentralised governance models play a crucial role in Web 3.0. These models enable stakeholders to participate in the decision-making processes that shape the development and evolution of the web (Brito et al., 2020; Chotkan et al., 2022). This enables individuals to have a say in protocol upgrades, network rules, and resource allocation. This participatory approach fosters transparency, accountability and community-driven development. By embracing decentralisation, Web 3.0 aims to reduce the concentration of power, enhance data security and privacy, foster innovation, and create a more resilient and democratic web ecosystem (Li et al., 2017b).

4.7 *Trustworthiness*

Web 3.0 establishes trust among participants through various mechanisms, ensuring transparency and integrity in transactions and interactions. Blockchain technology forms an immutable ledger. It is verifiable, allowing participants to independently validate the authenticity and accuracy of information (Tapscott and Tapscott, 2016). Cryptographic protocols ensure secure communication and verification, enhancing trust in data exchange and identity management. Absolutely, trust is a crucial element in Web 3.0, and it is achieved through various mechanisms that prioritise transparency, integrity, and security. The underlying technology that plays a key role in establishing trust in This transparency enhances trust by reducing the reliance on centralised authorities and creating a system where the integrity of transactions can be easily verified.

In addition to transparency, cryptographic protocols play a significant role in ensuring trust in Web 3.0. Public-key cryptography, for instance, enables secure communication and verification of digital signatures. Through the use of cryptographic keys, participants

can securely authenticate their identities, sign transactions, and encrypt sensitive data. This ensures that data exchanges and interactions within the Web 3.0 ecosystem are secure and tamper-proof, mitigating fraud, and manipulation. Furthermore, consensus mechanisms employed in Web 3.0, contribute to trust by ensuring agreement and validation of transactions across the network. These mechanisms prevent malicious actors from tampering with the ledger. By leveraging protocols, and consensus mechanisms, Web 3.0 establishes trust among participants. It promotes transparency, security, and verifiability, enabling users to have confidence in the accuracy of transactions, the protection of their data. This forms the foundation for the development of DApps, secure digital identities, and reliable interactions within the Web 3.0 ecosystem.

4.8 Reliability

Web 3.0 aims to provide a more reliable infrastructure compared to its predecessors. It achieves this through redundant and distributed architectures. If one node goes offline or experiences issues, other nodes continue to operate, ensuring uninterrupted availability of services. Additionally, Web 3.0 networks employ consensus algorithms that guarantee data consistency and integrity, further enhancing the reliability of the system. These measures contribute to a more robust and resilient web ecosystem. Absolutely, reliability is a crucial aspect of Web 3.0, and it is achieved through redundant and distributed architectures. Web 3.0 networks leverage decentralised and distributed technologies to enhance the reliability of the infrastructure compared to previous web generations. This distributed storage model provides redundancy, meaning that even if one or several nodes go offline or experience issues, other nodes in the network maintain copies of the data and continue to operate. This redundancy ensures availability of services even in the presence of node failures or disruptions. It creates a fault-tolerant system where the failure of individual nodes does not result in the loss of data or service interruptions. Furthermore, Web 3.0 networks employ consensus algorithms to ensure data consistency and integrity across the distributed network. By combining distributed storage and consensus algorithms, Web 3.0 creates a more reliable infrastructure compared to previous web generations. The redundancy in data storage and the ability to achieve consensus across the network contribute to a robust and resilient web ecosystem. Even in the presence of node failures, disruptions, or malicious attacks, Web 3.0 networks are designed to continue functioning, ensuring the reliability and availability of services for users.

4.9 Accessibility

Web 3.0 places a strong emphasis on accessibility to ensure that digital services are available to all. This is followed to make websites and applications more inclusive. Web 3.0 technologies also support assistive technologies, such as screen readers and alternative input devices, enabling users with disabilities to access and interact with online content. By prioritising accessibility, Web 3.0 aims to remove barriers and provide equal access to digital services for everyone. Indeed, accessibility is a key focus of Web 3.0, aiming to ensure that digital services are accessible to all individuals. Web 3.0 technologies and design principles prioritise inclusivity and follow accessibility standards and guidelines to make websites and applications more accessible. One widely recognised set of guidelines is WCAG. WCAG outlines various success criteria and

techniques that web developers can implement to enhance accessibility. These guidelines cover aspects such as perceivability, operability, understandability, and robustness, ensuring that digital content is perceivable, usable, and understandable by a diverse range of users. Web 3.0 technologies also support assistive technologies, which are specialised tools and software that assist individuals with disabilities in accessing and interacting with digital content. This helps users with visual impairments, while alternative input devices enable users with motor disabilities to navigate websites and applications using adapted input methods. By prioritising accessibility in Web 3.0, developers and designers strive to remove barriers and provide equal access to digital services for everyone. This inclusive approach enhances the user experience for all users. This makes the Web accessible, usable, and enjoyable for a diverse range of individuals, fostering equal participation and inclusivity in the digital realm.

4.10 Usability

Usability is a key focus of Web 3.0, aiming to improve the overall user experience. UI and UX are designed to be intuitive, efficient, and user-friendly. Web 3.0 interfaces often provide seamless navigation, clear information hierarchy, and contextual guidance to help users interact with DApps effortlessly. Moreover, this integration enables intelligent interactions and personalised experiences, tailoring the web to individual user preferences. It prioritises usability. Usability is indeed a key focus of Web 3.0, aiming to improve the overall user experience and make DApps more accessible and intuitive for users. Web 3.0 interfaces are intuitive, efficient, and user-friendly. Web 3.0 interfaces often feature seamless navigation and clear information hierarchy, allowing users to easily understand and interact with DApps. Contextual guidance and prompts are employed to assist users in their interactions, ensuring that they can navigate through various functionalities and features effortlessly. These technologies enable intelligent interactions, allowing users to communicate with DApps using natural language or voice commands. Additionally, ML algorithms can learn from user preferences and behaviours, enabling personalised experiences and tailoring the web content to individual user needs. By streamlining navigation, improving information presentation, and leveraging intelligent technologies, Web 3.0 strives to make DApps more accessible and user-friendly for individuals, regardless of their technical expertise or familiarity with blockchain technology.

4.11 Innovation

Web 3.0 fosters innovation by providing developers with a platform to create and deploy DApps. The programmable nature of smart contracts allows for the creation of complex logic and automated workflows, enabling new business models and disrupting traditional industries. Indeed, Web 3.0 provides a fertile ground for innovation by empowering developers to create and deploy DApps (Buterin, 2015). Using DeFi, developers can explore new possibilities and build innovative solutions across various industries. The programmable nature of smart contracts is a key aspect of Web 3.0 that fuels innovation. This programmability allows developers to implement complex logic, automate processes, and create innovative workflows that were previously not possible in traditional centralised systems.

Buterin (2015) Additionally, Web 3.0 encourages open-source collaboration and community-driven development. The decentralised nature of the web enables developers to share their code, collaborate with others, and build upon existing projects. This culture of open-source development fosters innovation by allowing developers to learn from each other, share ideas, and collectively contribute to the advancement of the web ecosystem. The collaborative nature of Web 3.0 accelerates the pace of innovation and promotes the creation of novel and groundbreaking applications. By providing a platform for developers to explore decentralised technologies and enabling open collaboration, Web 3.0 paves the way for disruptive innovations and the transformation of various industries.

4.12 Sustainability

Sustainability is a critical consideration in Web 3.0. Blockchain networks, which underpin Web 3.0 applications, have traditionally faced concerns regarding their energy consumption. However, Web 3.0 is actively exploring solutions to address these challenges. Additionally, efforts are being made to incorporate renewable energy sources into the operation of blockchain networks, further promoting sustainable practices within the Web 3.0 ecosystem. Indeed, sustainability is a crucial consideration in the development and implementation of Web 3.0. The energy consumption of blockchain networks, which underpin many Web 3.0 applications, has been a topic of concern. However, the Web 3.0 community is actively exploring solutions to address these challenges and promote sustainable practices.

Furthermore, efforts are being made to incorporate renewable energy sources into the operation of blockchain networks. By utilising renewable energy for mining and network infrastructure, Web 3.0 aims to minimise its carbon footprint and promote sustainability. Initiatives are emerging to establish green mining practices and encourage the use of renewable energy within the Web 3.0 ecosystem. In addition to addressing energy consumption, Web 3.0 also promotes sustainability through its decentralised nature. By eliminating intermediaries and reducing reliance on centralised systems, Web 3.0 can contribute to a more resilient and sustainable digital infrastructure. DApps and platforms built on Web 3.0 principles have the potential to reduce waste, enhance resource allocation, and enable more efficient and transparent processes. Overall, sustainability is a key consideration in Web 3.0, and the community is actively exploring solutions to mitigate energy consumption and promote environmentally friendly practices. By transitioning to more energy-efficient consensus mechanisms and incorporating renewable energy sources (Li et al., 2017A), Web 3.0 aims to align technological innovation with sustainable development goals.

4.13 Openness

Web 3.0 promotes an open and permissionless ecosystem, allowing anyone to participate, contribute, and build on the platform without unnecessary barriers. Open standards, protocols, and APIs enable interoperability and facilitate the integration of different applications and services. Furthermore, decentralised governance models, such as DAOs (Chotkan et al., 2022), ensure inclusivity. By embracing openness, Web 3.0 encourages collaboration, innovation, and the free flow of information, fostering a more democratic and egalitarian web environment. Web 3.0 indeed promotes an open and permissionless ecosystem, aiming to remove unnecessary barriers and enable broad participation and

collaboration. This open nature is foundational to the principles of Web 3.0 and has several key implications. Firstly, Web 3.0 embraces open standards, protocols, and APIs, which facilitate interoperability among different applications and services. By adopting these open technologies, developers can create DApps that can seamlessly interact with other DApps, forming a cohesive and interconnected web ecosystem. This interoperability enables innovation, as developers can leverage existing functionalities and services to build upon and enhance their own applications. Secondly, Web 3.0 promotes decentralised governance models, such as DAOs (Chotkan et al., 2022). DAOs leverage blockchain technology and smart contracts to automate governance mechanisms (Buterin, 2015), enabling participants to collectively make decisions, propose changes, and allocate resources within the network. This distributed decision-making fosters a more democratic and participatory approach to governance, giving stakeholders a voice. Additionally, the openness of Web 3.0 extends to the availability and accessibility of information. This allows for the free flow of information, empowering individuals to access and share knowledge without censorship or restrictions. This openness encourages collaboration, knowledge exchange, and collective problem-solving, fostering innovation and collective dependence. Furthermore, the permissionless nature of Web 3.0 means that anyone can participate and contribute to the ecosystem. This inclusivity empowers individuals from diverse backgrounds and regions to engage with Web 3.0 technologies, fostering a more egalitarian and inclusive web environment. It provides opportunities for individuals and communities to create, innovate, and benefit from the web without being limited by gatekeepers or traditional hierarchical structures. In summary, Web 3.0's emphasis on openness promotes collaboration, innovation, and the free flow of information.

4.14 Governance

DAOs enable collective decision-making by involving token holders or community members in the governance process (Chotkan et al., 2022). Through voting and consensus mechanisms, stakeholders can participate in determining the direction of the platform, proposing and implementing changes, and managing resources. This decentralised governance model fosters transparency, accountability and inclusivity. By giving power and control to the community, Web 3.0 promotes a more equitable and resilient governance structure, reducing reliance on centralised authorities. Web 3.0 indeed introduces new governance models that deviate from traditional centralised approaches, emphasising decentralised governance mechanisms such as DAOs. These new models have significant implications for the way platforms and communities are governed in the Web 3.0 ecosystem. This enables collective decision-making by involving token holders or community members (Chotkan et al., 2022). This decentralised governance model empowers stakeholders to actively participate in shaping the direction and governance of the platform they are involved in. One of the key aspects of DAOs is the ability for stakeholders to vote and reach consensus on important decisions. Through voting mechanisms, token holders or community members can express their opinions and preferences on various proposals, including protocol upgrades, resource allocation, and governance rules. The voting process is often transparent and verifiable, ensuring accountability and trust within the community.

Furthermore, DAOs facilitate a more inclusive approach to decision-making by providing opportunities for individuals to contribute based on their stake or expertise.

This inclusivity promotes a more diverse range of perspectives and encourages collective dependence and problem-solving. The use of blockchain technology ensures that decisions and transactions are recorded on a transparent and immutable ledger, enhancing accountability and preventing manipulation (Tapscott and Tapscott, 2016). Additionally, decentralised governance models in Web 3.0 reduce reliance on centralised authorities. They distribute power and decision-making across the network, reducing the influence of a few entities or individuals. This resilience makes the governance structure more robust and resistant to external control or manipulation. In summary, decentralised governance mechanisms, such as DAOs, form an integral part of Web 3.0 (Chotkan et al., 2022). They enable collective decision-making, transparency, inclusivity, and accountability within the ecosystem. By embracing decentralised governance models.

4.15 Economic empowerment

Web 3.0 aims to empower individuals economically by introducing new opportunities and models for value creation. Web 3.0 enables peer-to-peer transactions, eliminating the need for trusted third parties and reducing associated costs. This opens up avenues for new business models, crowdfunding initiatives, and the creation of digital economies. By enabling economic empowerment, Web 3.0 promotes financial inclusion, innovation, and the redistribution of wealth in a more equitable manner. Web 3.0 indeed aims to empower individuals economically by introducing new opportunities and models for value creation. DeFi applications leverage blockchain technology and smart contracts to facilitate peer-to-peer transactions, enabling users to lend, borrow, trade, and invest directly with each other (ElGayyar et al., 2020). This decentralised approach reduces transaction costs, and provides individuals with greater control over their financial activities. One of the key advantages of DeFi is its inclusivity. Web 3.0 enables global access to financial services, allowing individuals from all over the world to participate in the decentralised economy (Swan, 2015).

Tokenisation is another important aspect of Web 3.0 that contributes to economic empowerment (Chen et al., 2022). By tokenising real-world assets or creating new digital assets, individuals can represent ownership and value digitally. These tokens can then be traded, exchanged, or utilised within decentralised ecosystems. This opens up opportunities for new business models, crowdfunding initiatives, and the creation of digital economies. Web 3.0 also promotes financial innovation by fostering collaboration and experimentation. Developers and entrepreneurs can build on open protocols and standards, creating innovative DeFi applications and services. This encourages competition and drives the development of new solutions. Moreover, Web 3.0 promotes the redistribution of wealth in a more equitable manner. By removing barriers and intermediaries, individuals can participate directly in value creation and capture the benefits of their contributions. This reduces reliance on centralised institutions and creates a more inclusive and fair economic system. Overall, Web 3.0 empowers individuals economically by facilitating tokenisation, promoting financial inclusion, fostering innovation, and facilitating the redistribution of wealth. Through these mechanisms, Web 3.0 paves the way for a more equitable and inclusive economic landscape.

5 Performance evaluation

This section of the review presents the reader with a comparative analysis of each iteration of the Web based on certain parameters. This comparison employs scalability, speed, interoperability, security, privacy, decentralisation, trustworthiness, accessibility, reliability and usability as the parameters. The findings of the aforementioned comparative analysis have been displayed in Table 2. Furthermore, a detailed description of each iteration of the Web based on technological advancements, UX, socio-economic implications and security has been provided in this section, to enable the reader to gain a better understanding of the comparative analysis.

5.1 *Technological advancements and innovations*

Web 3.0 brought forth a range of technological advancements and innovations that revolutionised the capabilities and possibilities of the web ecosystem. These advancements paved the way for a more intelligent, decentralised, and interconnected web experience. The following section provides insights on some of the key technological advancements and innovations of Web 3.0.

- **Blockchain technology:** Blockchain is one of the most transformative technological advancements of Web 3.0. It provides a decentralised and secure framework for data storage, transactions and smart contracts. Blockchain technology ensures data integrity, immutability and transparency thereby eliminating the need for intermediaries and enabling trust less interactions. With advancements in consensus algorithms, scalability solutions and interoperability protocols, blockchain technology is becoming more efficient and adaptable and hence expanding its applications beyond cryptocurrencies.
- **Decentralised storage and content delivery:** Web 3.0 introduced decentralised storage systems that enabled the distributed storage and sharing of data. Technologies like interplanetary file system (IPFS) and file coin allow users to store files. decentralised CDNs leverage peer-to-peer protocols to distribute and serve information efficiently, thereby reducing latency and reliance on centralised servers.
- **DLT:** Alongside blockchain, Web 3.0 employed the use of other DLT. For instance, directed acyclic graph (DAG)-based platforms such as IOTA and Hedera Hash graph offer scalability and better transaction processing without traditional blocks and chains. These DLTs provide alternatives to blockchain thereby enabling high-throughput and feeless transactions and hence facilitating the integration of IoT devices into the web ecosystem (Kshetri, 2017).
- **AI and ML:** AI and ML technologies have been instrumental in Web 3.0, enabling intelligent data analysis and prediction, automation. NLP algorithms enabled machines to understand language, facilitating conversational interfaces and chatbots. ML algorithms process a huge amount of data, extract patterns and make predictions or recommendations based on user behaviour. This enabled the Web to provide the user with personalised experiences and information. AI and ML technologies also play a role in automated decision-making, anomaly detection and fraud prevention within decentralised systems.

- IoT integration: Web 3.0 integrates IoT devices into its web ecosystem, enabling them to interact with decentralised networks and services. IoT devices generate massive amounts of data that can be leveraged to create intelligent and context-aware applications. IoT facilitates smart homes, smart cities and industrial automation. By connecting IoT devices with blockchain and decentralised platforms, Web 3.0 increased privacy and interoperability in the IoT landscape (Kshetri, 2017).
- Semantic web technologies: Web 3.0 incorporates semantic web technologies that enhance the understanding and interpretation of data. These technologies enable machines to understand the meaning and relationships between different data elements, fostering intelligent search, data integration and knowledge representation.
- Privacy-enhancing technologies: Web 3.0 employs privacy-enhancing technologies to protect user data and ensure confidentiality.
- Smart contracts and DApps: Smart contracts residing on blockchain platforms enable the automation and execution of self-enforcing agreements. These contracts facilitate trustless interactions, enabling DApps to operate transparently and autonomously. DApps leverage blockchain's decentralised nature to provide services such as decentralised exchanges and intellectual property protection. This technology has revolutionised traditional industries by removing intermediaries, reducing costs and increasing transparency.

The aforementioned technological advancements and innovations of Web 3.0 have driven the transformation of the Web ecosystem, enabling a more secure, intelligent and decentralised digital landscape. As these technologies continue to evolve, they empower individuals in unprecedented ways.

5.2 User experiences and interaction paradigms

Web 3.0 introduced new UX and interaction paradigms that enhanced user engagement, personalisation and seamless interactions within the web ecosystem. These advancements aimed to provide users with intuitive, immersive and context-aware experiences. The following section provides insights on some of the key UX and interaction paradigms of Web 3.0 in more detail.

- Personalised experiences: Websites and applications analyse user behaviour, preferences and contextual information to provide tailored content, recommendations and services.
- Immersive interfaces: Web 3.0 incorporated immersive technologies that helped to create interfaces that provide users with more interactive and engaging experiences by blending digital content with the physical environment. Immersive interfaces have applications in gaming, training simulations, virtual meetings and virtual tours, enabling users to interact in a more natural and immersive manner.
- Conversational interfaces: Web 3.0 introduced conversational interfaces, powered by NLP and AI algorithms. Chatbots and intelligent assistants enabled users to interact with websites and applications through natural language conversations. This enabled users to ask questions, request information, perform tasks and receive personalised recommendations, making interactions more intuitive and efficient. Conversational

interfaces enhanced accessibility and enabled seamless interactions, particularly in mobile and voice-based environments (Cajas et al., 2020).

- **Context-aware experiences:** Web 3.0 utilised the assistance of contextual information to provide more relevant and context-aware experiences. By leveraging location data, sensor inputs and user preferences, applications can adapt their functionality and content based on the user's current context. For example, a travel application can provide personalised recommendations based on the user's location, preferences and past travel history. Context-aware experiences enhance user satisfaction and efficiency by delivering targeted information and services.
- **Multi-device interactions:** Web 3.0 focused on enabling seamless interactions across multiple devices and platforms. Users were able to start an activity on one device and seamlessly transition to another device without losing their progress. For example, a user can start reading an article on their smartphone and continue reading from the same point on their laptop. Multi-device interactions provided a consistent and uninterrupted user experience thereby accommodating the needs and preferences of users who switch between devices frequently.
- **Decentralised social interactions:** Web 3.0 introduced network and collaboration platforms. These platforms enabled users to interact, connect and collaborate in a peer-to-peer manner without relying on centralised social media platforms. Decentralised social interaction platforms prioritised privacy, data ownership and user control over personal information. Users had the ability to share content, engage in discussions and build communities in a more transparent, secure and decentralised manner.
- **Gamification and incentivisation:** Web 3.0 incorporated gamification elements and incentivisation mechanisms to enhance user engagement and participation. By leveraging blockchain technology and cryptocurrencies, users were able to earn rewards, tokens or digital assets for their contributions, participation in decentralised networks or for performing specific tasks. Gamification and incentivisation fostered user loyalty and motivated active participation thereby creating vibrant communities within the web ecosystem.
- **Data ownership and control:** Users had the ability to decide how their data was shared and utilised. Decentralised identity systems and cryptographic techniques enabled users to authenticate and verify their identities securely. Data ownership and control policies put users in the driver's seat, enhancing trust and privacy in the digital landscape.

The aforementioned UX and interaction paradigms of Web 3.0 aim to provide users with more intuitive, personalised and immersive experiences. By leveraging advanced technologies, contextual information and user-centric design principles, Web 3.0 revolutionised the way users interact with the web, enhancing engagement, satisfaction and efficiency.

5.3 Social and economic implications

Web 3.0 showcased significant social and economic implications. These implications were derived from the decentralised, user-centric and empowering nature of Web 3.0.

The following section explores the social and economic implications of Web 3.0 in more detail.

- **Democratisation of opportunities:** By removing intermediaries and reducing barriers to entry, individuals from all backgrounds were able to participate in decentralised networks, access financial services and engage in global markets. This democratisation enabled greater economic inclusion and empowered individuals who were previously underserved or excluded from traditional systems.
- **Economic empowerment:** Web 3.0 introduced new economic models and opportunities such as cryptocurrencies, DeFi (Buterin, 2015) and tokenisation. These enabled individuals to participate in the digital economy, invest in emerging projects and contribute to decentralised networks. Web 3.0 allowed for peer-to-peer transactions and direct value exchange, reducing the need for traditional intermediaries and potentially enabling individuals to retain a larger share of the economic value they generate (Swan, 2015).
- **Trust and transparency:** Web 3.0's decentralised and transparent nature fostered trust among participants (Buterin, 2015). Blockchain technology ensured data integrity, immutability and accountability. This transparency had far-reaching implications, from reducing corruption and fraud to enabling more trustworthy governance and decision-making processes. The ability to verify the authenticity and provenance of information and goods enhanced consumer trust and safety.
- **Data ownership and privacy:** Web 3.0 prioritised data ownership and privacy, which enabled users to have greater control over their personal data and decide how their data was shared and utilised. This shift empowered individuals to protect their privacy, reduce the risk of data breaches and potentially monetise their data. The emphasis on data ownership and privacy aligned with evolving societal values regarding the protection of personal information and the need for consent-driven data practices.
- **Disintermediation and cost reduction:** Web 3.0 reduced the reliance on intermediaries by enabling direct peer-to-peer interactions. This disintermediation had the potential to lower the costs that were associated with traditional centralised systems. Financial transactions could be conducted without intermediaries like banks, hence reducing transaction fees (Amalia, 2016). Similarly, the elimination of intermediaries in content distribution enabled content creators to monetise their work more directly, ensuring a fairer distribution of revenue.
- **Innovation and collaboration:** Web 3.0 fostered innovation and collaboration through open-source development, decentralised protocols, and interoperability. Developers were able to leverage existing functionalities and build upon them, accelerating the pace of innovation. Collaboration became easier as decentralised networks facilitated trustless interactions and allowed individuals to contribute their expertise without relying on centralised gatekeepers (Buterin, 2015).
- **Digital identity and inclusion:** Web 3.0 addressed the challenges of digital identity by providing decentralised identity systems. Users had greater control over their digital identities, which enhanced privacy, security and inclusion. Web 3.0 facilitated access

to services, education and financial systems for individuals without traditional identification documents, contributing to social inclusion and empowerment.

- **Civic engagement and governance:** Web 3.0 has the potential to transform civic engagement and governance processes. The transparency and auditability of blockchain technology can enhance trust (Buterin, 2015), allow for more inclusive and transparent decision-making, where individuals can vote, propose, and influence the direction of projects and organisations.
- **Sustainability and environmental impact:** Web 3.0 introduced opportunities for sustainability and reduced environmental impact. By leveraging decentralised infrastructure and consensus mechanisms, energy consumption and carbon footprints can be minimised compared to traditional centralised systems. Additionally, Web 3.0's potential to enable sharing economies, peer-to-peer energy trading and resource optimisation can contribute to more sustainable consumption patterns (Li et al., 2017a).
- **Formation of new economic models:** The increase in utilisation of DAOs and token-based incentive systems has led to the formation of new economic models. This transformation ensured disruption and leveraged disruptive technologies. This led to the widening in social disparities amidst the ongoing improvements in cost, competency, efficiency and connectivity of the web. Additionally this highlights the importance of sense-making and the expansion of interconnected networks, which fostered various business opportunities within an increasingly fragile economic landscape. Intellectual property rights played a pivotal role in shaping the dynamics of this ecosystem.

While Web 3.0 presents numerous social and economic benefits, it is important to acknowledge the challenges and risks that may arise within its digital ecosystem. These include regulatory complexities, scalability issues, the potential for increased inequality, and the need for digital literacy and security measures. Addressing these challenges will be crucial in harnessing the full potential of Web 3.0 and ensuring its positive impact on society and the economy (Swan, 2015).

5.4 Privacy, security, and trust

Privacy, security, and trust are fundamental concerns in the digital landscape, and Web 3.0 introduces new approaches and considerations in these areas. As Web 3.0 embraces decentralisation and user-centricity, it strives to enhance privacy, strengthen security and foster trust in online interactions. The following section explores the aforementioned aspects in more detail:

- **Privacy:** Web 3.0 prioritises user privacy by providing individuals with greater control over their personal data. Users can engage in transactions, communications and online activities without revealing unnecessary personal information, fostering privacy in the digital realm (Söllner and Leimeister, 2016).
- **Data ownership and control:** Web 3.0 shifts the paradigm of data ownership, allowing users to own and control their data. Blockchain technology enables users to determine how their data is used, shared and monetised. With decentralised storage systems, individuals can store data across a network of nodes, reducing reliance on

centralised entities that may exploit or mishandle personal information. By empowering users with data ownership and control, Web 3.0 has restored trust and provided individuals with an agency over their digital footprint.

- **Secure and immutable transactions:** Web 3.0 leverages blockchain technology to ensure secure and immutable transactions. Transactions recorded on the blockchain are cryptographically secured, providing integrity and authenticity. Smart contracts enable self-executing agreements, enforcing the agreed-upon terms without the need for intermediaries. These secure and transparent transaction mechanisms foster trust among participants and mitigate risks associated with traditional centralised systems.
- **Enhanced security measures:** Web 3.0 embraces enhanced security measures to protect users from cyber threats. Encryption techniques, multi-factor authentication, and decentralised identity systems contribute to strengthened security measures (Li et al., 2017b). However, it is important to note that Web 3.0 is not immune to security vulnerabilities, and continuous efforts are required to address emerging risks and ensure a secure digital environment.
- **Trustless interactions and smart contracts:** Web 3.0 fosters trust among participants through transparency and verifiability. The immutability of smart contracts ensures that agreements cannot be tampered with, enhancing trust in online transactions and reducing the potential for disputes.
- **Regulatory and legal considerations:** As Web 3.0 evolves, there is greater need to address regulatory and legal considerations. With the rise in decentralised networks, traditional regulatory frameworks may need to adapt to accommodate the unique features and challenges of Web 3.0. Legal frameworks related to data protection, digital identities, smart contracts and dispute resolution may require updates to ensure privacy, security, and trust in Web 3.0 environments.

While Web 3.0 offers promising advancements in privacy, security, and trust, it is important to recognise that challenges and risks still exist. These include the potential for new types of vulnerabilities, the need for user education on secure practices, and the responsibility of developers to build robust and audited systems. Striking a balance between privacy, security, and trust will be crucial in fostering a resilient and trusted Web 3.0 ecosystem.

5.5 Potential challenges and limitations

While Web 3.0 brings forth exciting possibilities and transformative potential, it also faces certain challenges and limitations that need to be addressed for its widespread adoption and success. Understanding these challenges is essential for developing strategies to overcome them. The following section explores some of the key challenges and limitations associated with Web 3.0 in more detail:

- **Scalability:** Blockchain-based systems, which are often at the core of Web 3.0 applications, face limitations in terms of transaction throughput and processing capacity. As more users join the network and the volume of transactions increases, scalability becomes crucial to maintain efficiency and user experience. Scaling solutions, such as layer-2 protocols, sharding, and off-chain transactions, are being developed to address this challenge.

- **User experience:** The current state of some DApps falls short in terms of usability and intuitiveness compared to their centralised counterparts. The learning curve associated with managing private keys, interacting with blockchain interfaces and understanding the intricacies of decentralised systems can be a barrier for mainstream adoption. Improving user experience design and providing user-friendly interfaces will be essential in driving broader adoption of Web 3.0 technologies.
- **Interoperability:** Web 3.0 envisions a highly interconnected and interoperable ecosystem where different DApps and blockchain networks can seamlessly interact. However, achieving interoperability among various blockchain protocols, each with its own technical specifications and consensus mechanisms, poses a significant challenge. Standards and protocols, such as cross-chain communication protocols and interoperability frameworks, are being developed to facilitate seamless data exchange.
- **Regulatory environment:** The regulatory landscape surrounding Web 3.0 technologies and applications is continuously evolving. Uncertainty and inconsistent regulations in different jurisdictions can create barriers to innovation and hinder the development of Web 3.0 projects. Striking the right balance between protecting user interests, ensuring compliance and fostering innovation is crucial.
- **Energy consumption:** While efforts are being made to develop more energy-efficient consensus algorithms and promote sustainable mining practices, addressing the energy consumption challenge remains vital to ensure the long-term sustainability and viability of Web 3.0 technologies (Li et al., 2017a).
- **Governance and coordination:** Web 3.0 introduced decentralised governance models, such as DAOs. While decentralised governance promotes transparency and inclusivity, it also raises challenges related to decision-making processes, coordination, and accountability. Balancing decentralised decision-making with the need for efficient coordination and resolving disputes in a decentralised manner is an ongoing challenge.
- **Security risks:** Smart contract bugs, hacking attempts and malicious activities can pose significant risks to Web 3.0 applications and the funds/assets stored within them. Secure coding practices, rigorous auditing and ongoing security assessments are crucial to mitigate these risks. Additionally, educating users about best security practices, such as safeguarding private keys and utilising secure wallets is essential to protect against potential threats.
- **Adoption and education:** Educating users about the benefits, functionalities and risks associated with Web 3.0 is crucial for mainstream adoption. Promoting digital literacy, creating user-friendly educational resources and demonstrating real-world use cases and benefits will be key to driving adoption and expanding the user base of Web 3.0 applications.

Addressing these challenges and limitations will require collaboration among various stakeholders including developers, regulators, industry leaders and users. Continuous innovation, research and development efforts, along with iterative improvements to the underlying technologies and infrastructure will be crucial to unlocking the full potential

of Web 3.0 and overcoming these hurdles. Table 3 shows the key differences between limitations of each iteration of the web.

6 Discussions

6.1 Anticipated Web 3.0 applications

The characteristics of Web 3.0 have been represented in Figure 10. Web 3.0 holds the promise of enabling a wide range of innovative applications and transforming various industries. These anticipated applications leverage the decentralised, user-centric, and trust-enhancing features of Web 3.0 technologies. The following section explores some of the key areas where Web 3.0 is expected to have a significant impact:

- **DeFi:** DeFi is one of the most prominent and rapidly growing areas within the Web 3.0 ecosystem. It encompasses a range of financial services and applications built on blockchain technology (Mougayar, 2016), including decentralised lending and borrowing, decentralised exchanges, yield farming and decentralised stablecoins. DeFi eliminates intermediaries and enables peer-to-peer transactions and provides users with greater control over their assets and financial activities (Amalia, 2016).
- **Digital identity and SSI:** Web 3.0 offers a new approach to digital identity management, empowering individuals with self-sovereign identities. Its applications are identity verification, secure authentication, and privacy protection in various domains, including financial services, healthcare, and governance.
- **Supply chain management:** Web 3.0 has revolutionised supply chain management by providing transparent, traceable and immutable records of goods and transactions. Blockchain-based supply chain solutions enhance transparency, enable end-to-end traceability and facilitate efficient inventory management and logistics (Mougayar, 2016). These applications can help mitigate counterfeiting thereby ensuring product authenticity and improving supply chain efficiency and sustainability.
- **IoT:** Web 3.0 can leverage the potential of IoT by enabling secure, decentralised and autonomous interactions between IoT devices. Blockchain technology provides a trust layer for IoT networks ensuring data integrity, secure communication and decentralised control. Web 3.0 can enable secure peer-to-peer transactions and coordination among IoT devices, creating new possibilities for smart homes, connected cities and industrial IoT applications (Kshetri, 2017).
- **Content creation and distribution:** Content creators can leverage decentralised platforms and blockchain-based systems to publish, protect and monetise their creative works without relying on intermediaries. Smart contracts enable direct interactions between content creators and consumers, ensuring fair compensation and more transparent revenue sharing models (Buterin, 2015).
- **Decentralised social networking:** Decentralised social networking platforms aim to give users ownership of their data, enable privacy-enhancing features and provide incentive mechanisms for content creation and curation. These platforms prioritise user-centricity, data privacy and the removal of centralised authority in social interactions.

- Voting systems: DAOS enable voting, proposal submission and fund allocation through transparent and decentralised mechanisms. These governance systems aim to enhance transparency, inclusivity and accountability in organisational decision-making.
- Energy trading and grid management: Web 3.0 can transform the energy sector by facilitating peer-to-peer (P2P Foundations) energy trading, decentralised energy markets and grid management. Smart grids powered by Web 3.0 technologies can improve energy efficiency, enable dynamic pricing and enhance grid resilience (Hileman and Rauchs, 2017).
- These are just a few examples of the anticipated applications that Web 3.0 can bring forth. As the technology continues to evolve and mature, new and unforeseen applications are likely to emerge, disrupting industries and transforming the way we interact, transact and engage in various aspects of our lives.

6.2 *Integration of Web 2.0 and Web 3.0 features*

As the transition from Web 2.0 to Web 3.0 unfolds, there is an opportunity for the integration of features from both generations of the web. By combining the strengths of Web 2.0 and Web 3.0, developers and users can benefit from enhanced functionalities, improved UX and increased adoption. The following section explores some key aspects of integrating the features of Web 2.0 and Web 3.0:

- User experience: Web 2.0 has excelled in delivering intuitive UX with its user-friendly interfaces and interactive features. Integrating the design principles and usability standards of Web 2.0 into the applications of Web 3.0 can enhance user adoption and engagement. By leveraging the best practices of Web 2.0 such as responsive design, seamless navigation and visually appealing interfaces, Web 3.0 applications can provide a familiar and enjoyable user experience.
- Data accessibility: Web 2.0 enabled the democratisation of information by allowing users to easily access and contribute to online content. Integrating the data accessibility features of Web 2.0 with Web 3.0 can ensure that the decentralised web remains inclusive and user-centric. This includes providing open APIs, allowing seamless data sharing and integration across different platforms and enabling users to easily import and export their data from Web 3.0 applications.
- Social interactions: Web 2.0 platforms have revolutionised social interactions by enabling users to connect, share and collaborate. Integrating social features from Web 2.0 applications into Web 3.0 applications can foster community engagement and user participation. This can include features such as user profiles, social feeds, commenting systems and collaborative tools, allowing users to interact with each other and form communities within the decentralised web.
- Identity management: Web 2.0 platforms rely on centralised identity systems, often requiring users to create multiple accounts across different platforms. By integrating Web 3.0's SSI capabilities into Web 2.0 applications, users authenticate themselves across various platforms without the need for multiple logins or third-party identity providers.

- Payments and micropayments: Web 3.0 introduces native cryptocurrency and blockchain-based payment systems, allowing for secure and frictionless peer-to-peer transactions (Hileman and Rauchs, 2017). Integrating Web 3.0 payment functionalities into Web 2.0 applications can enable seamless and borderless financial interactions (Amalia, 2016). This integration can support various use cases, including content monetisation, in-app purchases and peer-to-peer transactions, while leveraging the security and efficiency of Web 3.0 payment infrastructures.
- Smart contracts and automation: Integrating this technology into Web 2.0 applications can enhance automation, streamline workflows and ensure trustworthiness in transactions. This integration can enable features such as automatic verification, secure escrow services and transparent contract execution, bringing efficiency and reliability to Web 2.0 processes (Buterin, 2015).
- Hybrid infrastructure: Web 2.0 applications typically rely on centralised servers and cloud infrastructure for data storage and processing. Integrating Web 3.0's decentralised storage and computation capabilities into Web 2.0's applications can enhance data privacy, security and resilience. By leveraging decentralised networks, such as IPFS or Swarm, Web 2.0 applications can ensure data availability, eliminate single points of failure and protect user data from unauthorised access.
- Governance and consensus: Web 3.0 introduces decentralised governance models, enabling users to participate in decision-making processes. Integrating governance mechanisms from Web 3.0 into Web 2.0 applications can foster transparency, inclusivity, and user empowerment. This integration can involve features such as voting systems, decentralised consensus mechanisms, and community-driven decision-making, allowing users to have a say in the direction and evolution of Web 2.0 platforms (Brito et al., 2020).

The integration of Web 2.0 and Web 3.0 features brings together the best of both worlds, combining the user-centric design and familiarity of Web 2.0 with the decentralised, trust-enhancing capabilities of Web 3.0. This integration can drive broader adoption, bridge the gap between the two generations of the Web and accelerate the transition towards a more decentralised and user-empowered internet.

6.3 Ethical considerations

As we explore the potential of Web 3.0 and its transformative capabilities, it is important to address development and deployment. Ethical considerations play a crucial role in ensuring that Web 3.0 technologies and applications are designed, implemented and used in a responsible and socially beneficial manner (Carrier and Luetchford, 2012). The following section examines some key ethical considerations related to Web 3.0:

- Privacy and data protection: Web 3.0 introduces new paradigms for data ownership and control. It is essential to prioritise user privacy and data protection in Web 3.0 applications. Transparent data collection practices, informed consent mechanisms, robust encryption and secure storage should be implemented to safeguard user data. Additionally, users should have the ability to manage and control the use of their personal information in a decentralised environment.

- **Security and trust:** Web 3.0 relies on blockchain technology, which introduces new security considerations. Implementing rigorous security protocols, conducting regular audits and providing clear security guidelines to users is crucial for maintaining trust in the Web 3.0 ecosystem (Li et al., 2017b).
- **Inclusivity and accessibility:** Web 3.0 should be open to all, irrespective of technical expertise, socio-economic status or geographical location. UI should be designed keeping accessibility standards in mind and efforts should be made to address the potential exclusionary effects of complex user requirements or high transaction costs.
- **Transparency and accountability:** Web 3.0 systems should strive for transparency and accountability. Smart contracts and decentralised governance models should be designed to ensure transparency in decision-making processes and allocation of resources. Additionally, mechanisms should be in place to address disputes, resolve conflicts and provide avenues for user feedback and redressal. Transparency in algorithmic decision-making, data processing and governance mechanisms is crucial for building trust and maintaining accountability.
- **Sustainability:** Web 3.0 technologies, particularly those relying on blockchain, can consume significant amounts of energy. This includes developing and implementing consensus mechanisms that minimise energy consumption, promoting renewable energy sources for mining and transaction processing and adopting sustainable practices throughout the Web 3.0 ecosystem (Li et al., 2017a).
- **Ethical use of data and AI:** Ethical considerations must be included for the collection, processing and utilisation of data in AI models to ensure fairness, transparency and accountability (Carrier and Luetchford, 2012). Safeguards should be in place to prevent biased outcomes, discriminatory practices and the unethical use of personal information.
- **Social impact and inequality:** Web 3.0 should be designed and deployed with consideration for its social impact. Efforts should be made to understand and mitigate potential negative consequences, such as exacerbating existing inequalities or concentrating power in the hands of a few. Web 3.0 projects should aim to address social challenges, promote social good and contribute to sustainable development.
- **Regulatory compliance:** Web 3.0 operates in a complex regulatory landscape. Ethical considerations involve complying with relevant laws and regulations, particularly those related to data privacy, consumer protection, financial regulations and anti-money laundering. Web 3.0 projects should work collaboratively with regulators, industry bodies and stakeholders to establish clear legal frameworks and ensure compliance with ethical standards.

Addressing these ethical considerations requires a multidisciplinary approach involving technologists, policymakers, ethicists, and users (Ritzer, 2019).

6.4 Societal implications

The emergence of Web 3.0 brings forth a range of societal understanding and addressing these implications is essential to harness the benefits of Web 3.0 while mitigating any

negative consequences. The following section presents some of the key societal implications of Web 3.0.

- **Democratisation of access:** This will democratise access to information, services, and opportunities. Decentralised platforms and blockchain-based systems can empower individuals by eliminating intermediaries, reducing barriers to entry, and enabling direct peer-to-peer interactions. This can promote inclusivity, broaden participation, and create new opportunities for individuals and communities, particularly in regions with limited access to traditional infrastructures.
- **Disintermediation and economic disruption:** By enabling peer-to-peer transactions, smart contracts, and decentralised governance, Web 3.0 can disrupt existing business models and reshape economic systems. While this can lead to greater efficiency, cost reduction, and innovation, it may also disrupt established industries and traditional employment structures. Ensuring a smooth transition and addressing the potential social and economic implications of disintermediation is crucial.
- **Digital trust and transparency:** Web 3.0 technologies, such as blockchain, provide enhanced trust and transparency through decentralised and immutable record-keeping. This can foster trust in transactions, reduce fraud, and increase accountability (Chen et al., 2022). However, it also raises questions about data privacy, as blockchain's transparent nature may expose sensitive information.
- **Governance and decentralised decision-making:** Web 3.0 introduces new models of governance and decision-making. DAOs allocate resources, and shape the direction of projects and communities. This shift towards decentralised governance raises questions about accountability, consensus-building, and the balance of power. Ensuring inclusive participation, addressing governance challenges, and establishing mechanisms for dispute resolution are vital for effective decentralised governance.
- **Data ownership and privacy:** Users can determine how their data is accessed, shared, and monetised. This shift challenges the existing data ownership and monetisation models, but also raises concerns about privacy, security, and the potential misuse of personal information (Li et al., 2017b). Striking a balance between data ownership, privacy protection and responsible data use is essential for the success of Web 3.0.
- **Digital identity and authentication:** While this can enhance privacy and security, it also poses challenges in terms of identity verification, trust establishment and the prevention of identity theft. Developing robust identity management solutions that prioritise privacy, security and user control is crucial for a successful transition to Web 3.0.
- **Digital divide and accessibility:** Web 3.0 has the potential to exacerbate existing inequalities if not properly addressed. The digital divide in terms of access to technology, connectivity and digital literacy, may hinder the widespread adoption and benefits of Web 3.0. Efforts should be made to bridge this divide to provide equal opportunities for participation to and ensure that Web 3.0 technologies are available to all.
- **Intellectual property and content ownership:** Blockchain-based systems enable creators to assert ownership over their digital assets, establish transparent licensing and royalty mechanisms and interact directly with their audience (Wu et al., 2022).

However, this also raises questions about copyright enforcement, intellectual property protection and the potential for unauthorised distribution and piracy. Balancing the rights of content creators, fostering creativity and respecting intellectual property laws are important considerations.

Understanding and proactively addressing these societal implications of Web 3.0 will help us navigate the transition and maximise its potential benefits. It requires collaboration between stakeholders, including technology developers, policymakers, regulators, civil society organisations and the public to ensure that Web 3.0 technologies contribute positively to society, promote inclusivity and uphold ethical and societal values (Ritzer, 2019).

To gain a clear picture on the evolution of the Web from static web pages that simply provided information rather than delivering content, to dynamic web pages that are user-centric, participatory and intelligent, a concise table containing the applications and use cases of each iteration of the web has been presented below. Table 4 depicts the applications of each iteration of the web. It is recommended to refer to Figure 7 alongside this table as they are interrelated.

7 Conclusions and future scope

7.1 Summary of findings

Throughout this research paper, we have explored the evolution and characteristics of Web 1.0, Web 2.0, and Web 3.0, examining their technological aspects, UX, implications, and potential benefits. The following section presents the reader with a summary on the key findings of the comparative analysis:

- Web 1.0: It primarily focused on information dissemination and lacked user participation and dynamic content generation.
- Web 2.0: Web 2.0 marked a significant shift towards user-centric experiences, social interactions, and participatory web applications. It introduced dynamic and interactive content, user-generated content, social media platforms, and collaborative tools. Web 2.0 emphasised user engagement, sharing, and networking.
- Web 3.0: Web 3.0 represents the next phase of the internet, with a focus on decentralisation, peer-to-peer interactions, and trust-enhancing technologies. Web 3.0 aims to empower users, prioritise data privacy, and establish trust in digital interactions (Wu et al., 2022).
- Technology and architecture: Web 3.0 introduces novel technologies and architectures, such as blockchain, distributed ledgers, decentralised storage, and peer-to-peer networks. These technologies enable data integrity, trust, and decentralisation, promoting secure and efficient peer-to-peer transactions, DApps, and transparent governance (Qin et al., 2023).
- User experience: Web 3.0 offers new UX characterised by greater user control, ownership of data and enhanced privacy. It empowers users to manage their digital identities, participate in decentralised governance, and have control over their personal information. However, challenges such as complex UI, scalability issues,

and the learning curve of using decentralised technologies need to be addressed for seamless adoption.

- **Implications and potential benefits:** Web 3.0 presents various implications and potential benefits. It has the potential to democratise access, disrupt traditional intermediaries, enhance transparency and trust, and promote user empowerment. Web 3.0 applications can enable new economic models, peer-to-peer collaboration, and decentralised decision-making. However, challenges related to regulatory compliance, privacy, sustainability and social impact require attention.
- **Integration of Web 2.0 and Web 3.0:** There is an opportunity for integrating features from both Web 2.0 and Web 3.0, combining user-friendly interfaces, social interactions, and data accessibility from Web 2.0 with the decentralisation, trust, and smart contract capabilities of Web 3.0. This integration can enhance UX, bridge the gap between the two generations of the web, and accelerate the adoption of Web 3.0 technologies.
- **Ethical considerations:** Web 3.0 requires careful consideration of ethical implications. Privacy protection, security, inclusivity, transparency, and responsible data use are critical ethical considerations. Collaboration among stakeholders is necessary to ensure that Web 3.0 technologies align with ethical principles and contribute positively to society (Ritzer, 2019).
- **Societal implications:** Web 3.0 has significant societal implications, including the democratisation of access, economic disruption, digital trust, decentralised governance (Buterin, 2015), data ownership, and the digital divide. Addressing these implications involves fostering inclusivity, transparency, accountability, and balancing the benefits of Web 3.0 with potential challenges and inequalities.

Further research, collaboration, and dialogue are essential to navigate its challenges, harness its potential, and ensure its positive impact on society.

7.2 Key takeaways

This review paper has examined the concepts and characteristics of Web 1.0, Web 2.0 and Web 3.0, by exploring their technological aspects, UX, implications and potential benefits. The following section contains the key takeaways of this review:

- **Evolution of the web:** The web has evolved from static pages and limited interactivity (Web 1.0) to user-centric experiences and participatory platforms (Web 2.0) and now towards decentralisation, trust, and empowerment (Web 3.0). Each phase has brought significant changes in how we access and interact with information and services online (Brito et al., 2020).
- **Web 3.0 technologies:** Web 3.0 relies on technologies such as blockchain, smart contracts, block storage, and peer-to-peer networks. These technologies enable secure transactions, transparent governance, data integrity, and SSI. They form the foundation of a decentralised and trust-enhancing internet ecosystem.
- **User empowerment:** Users have the ability to participate in decentralised governance, own and monetise their digital assets, and assert control over their

personal information. Web 3.0 aims to shift its power dynamics and enable its users to become more active.

- **Trust and transparency:** Web 3.0 has introduced transparency and trust through decentralised technologies. Blockchain-based systems provide tamper-proof and auditable records, enhancing trust in transactions and reducing reliance on intermediaries (Tapscott and Tapscott, 2016). This transparency fosters accountability and enables users to verify and authenticate information and transactions.
- **Ethical considerations:** Ethical considerations play a crucial role in the development and deployment of Web 3.0. Protecting user privacy, ensuring data security, promoting inclusivity and addressing the social impact of technological advancements are key ethical considerations. Responsible development and design practices are necessary to uphold ethical principles and mitigate potential risks (Carrier and Luetchford, 2012).
- **Societal impact:** Web 3.0 has far-reaching societal implications. It has the potential to democratise access to information and services, disrupt traditional industries and business models, empower individuals, and foster peer-to-peer collaboration. However, it also poses challenges such as the digital divide, economic disruptions and the need for new governance models.
- **Integration of Web 2.0 and Web 3.0:** Integrating features from Web 2.0 and Web 3.0 can bridge the gap between the two generations of the Web and enhance UX. By combining user-friendly interfaces, social interactions and data accessibility from Web 2.0 with the decentralisation and trust-enhancing capabilities of Web 3.0, we can create more seamless and user-centric applications.
- **Continuous learning and collaboration:** Web 3.0 is an evolving landscape, and there is much to learn and explore. Ongoing research, collaboration, and interdisciplinary approaches are necessary to address challenges, refine technologies, and maximise the potential benefits of Web 3.0. Collaboration between technologists, policymakers, ethicists, and users is crucial to shape the future of the internet in a responsible and inclusive manner.

The aforementioned key takeaways highlight the transformative nature of Web 3.0, its potential to reshape our interactions with the internet and the importance of ethical considerations and collaboration in its development. By embracing these insights, we can navigate a digital future that aligns with our values and aspirations.

7.3 Areas for further research

While this review has provided valuable insights into the concepts and implications of Web 3.0 and the evolution of the Web, there are several areas that warrant further investigation. These areas of research can help deepen our understanding and address the challenges and opportunities associated with Web 3.0. Here are some key areas for further research:

- **Scalability and performance:** Web 3.0 technologies face scalability and performance challenges. As the user base and transaction volume grow, it is crucial to explore

solutions that can handle increased demand without compromising performance. Research in this area can focus on optimising consensus mechanisms, improving network protocols, and developing efficient storage and computational solutions.

- **Governance and consensus models:** Further research is needed to explore effective governance mechanisms, consensus models, and dispute resolution mechanisms in decentralised environments. This research can contribute to the development of robust governance frameworks that promote inclusivity, transparency, and accountability.
- **Privacy-preserving technologies:** Web 3.0 emphasises user privacy and control over personal data. Research is needed to develop privacy-preserving technologies that can protect user identities, enable selective data sharing, and ensure secure transactions while maintaining compliance with privacy regulations. Exploring privacy-enhancing techniques such as ZKPs and secure multi-party computation can advance privacy in Web 3.0.
- **Interoperability and standards:** Research efforts can focus on developing interoperability frameworks, standards, and protocols that allow different DApps and platforms to communicate and interoperate effectively. This can facilitate a more connected and collaborative Web 3.0 ecosystem.
- **User experience design:** Enhancing UX in Web 3.0 applications is an ongoing challenge. Further research can explore user interface design, interaction paradigms, and user onboarding strategies to make Web 3.0 technologies more intuitive and accessible to a wider audience. Understanding user behaviours, preferences, and expectations in decentralised environments can lead to improved user adoption and engagement.
- **Environmental sustainability:** Web 3.0 technologies, particularly blockchain-based systems, consume significant computational resources and energy. Research is needed to develop energy-efficient consensus algorithms, sustainable mining practices, and eco-friendly infrastructure solutions. Exploring the environmental impact of Web 3.0 and identifying strategies to minimise its carbon footprint can contribute to a more sustainable digital future (Li et al., 2017a).
- **Socio economic impact:** Web 3.0 has the potential to impact socioeconomic structures and power dynamics. Further research can investigate the implications of Web 3.0 on employment, income distribution, wealth inequality, and social inclusion. Understanding the socioeconomic impact of Web 3.0 can inform policy-making and facilitate the development of measures to mitigate any negative consequences (Chen et al., 2022).
- **Legal and regulatory considerations:** Data protection, and consumer protection are important aspects to be taken into consideration. Research is needed to explore legal frameworks, regulatory mechanisms, and international collaborations that can address these challenges and ensure a balanced and fair digital environment (Wu et al., 2022).

It is important to note that collaborative research efforts involving academia, industry, policymakers, and user communities will be instrumental in advancing Web 3.0 technologies.

Appendices/Supplementary materials are available on request by emailing the corresponding author.

References

- Amalia, F. (2016) 'The fintech book: the financial technology handbook for investors, entrepreneurs and visionaries', *Journal of Indonesian Economy and Business*, Vol. 31, p.345, DOI: 10.22146/jieb.23554.
- Berners-Lee, T. and Mark, F. (1999) *Weaving the Web: The Original Design and Ultimate Destiny of the World Wide Web*, HarperOne, San Francisco.
- Brito, A.A., de Lima, S.E. Ferreira, V., de Arruda Burégio, V., Garcia, C. and de Lemos Meira, S.R. (2020) 'Evolution of the web of social machines: a systematic review and research challenges', in *IEEE Transactions on Computational Social Systems*, April, Vol. 7, No. 2, pp.373–388, DOI: 10.1109/TCSS.2019.2961269.
- Buterin, V. (2015) *A Next Generation Smart Contract & Decentralized Application Platform*, Ethereum White Paper.
- Cajas, V., Urbietta, M., Rossi, G. and Domínguez Mayo, F. (2020) 'Challenges of migrating legacies web to mobile: a systematic literature review', in *IEEE Latin America Transactions*, May, Vol. 18, No. 5, pp.861–873, DOI: 10.1109/TLA.2020.9082914.
- Canturk, D. and Karagoz, P. (2011) 'Using semantic information for distributed web service discovery', *Int. J. of Web Science*, Vol. 1, pp.21–35, DOI: 10.1504/IJWS.2011.044080.
- Carrier, J.G. and Luetchford, P.G. (2012) *Ethical Consumption: Social Value and Economic Practice*, Berghahn Books.
- Chen, C. et al. (2022) 'When digital economy meets Web3.0: applications and challenges', in *IEEE Open Journal of the Computer Society*, Vol. 3, No. 1, pp.233–245, DOI: 10.1109/OJCS.2022.3217565.
- Chotkan, R., Decouchant, J. and Pouwelse, J. (2022) 'Unstoppable DAOs for web3 disruption', in *Proceedings of the 3rd International Workshop on Distributed Infrastructure for the Common Good (DICG '22)*, Association for Computing Machinery, New York, NY, USA, pp.37–42, <https://doi.org/10.1145/3565383.3566112>.
- Doe, D. M., Li, J., Dusit, N., Gao, Z., Li, J. and Han, Z. (2023) 'Promoting the sustainability of blockchain in Web 3.0 and the metaverse through diversified incentive mechanism design', in *IEEE Open Journal of the Computer Society*, Vol. 4, pp.171–184, DOI: 10.1109/OJCS.2023.3260829.
- ElGayyar, M., El Yamany, H., Grolinger, K., Capretz, M. and Mir, S. (2020) 'Blockchain-based federated identity and auditing', *International Journal of Blockchains and Cryptocurrencies*, Vol. 1, p.179, DOI: 10.1504/IJBC.2020.109004.
- Grimmelmann, J. (2008) 'Saving Facebook', *Iowa Law Review*, Vol. 94, James Grimmelmann.
- Hileman, G. and Rauchs, M. (2017) *Global Blockchain Benchmarking Study*, September 22 [online] <https://ssrn.com/abstract=3040224> or <http://dx.doi.org/10.2139/ssrn.3040224>.
- Kshetri, N. (2017) 'Can blockchain strengthen the internet of things?', in *IT Professional*, Vol. 19, No. 4, pp.68–72, DOI: 10.1109/MITP.2017.3051335.
- Li, J., Shao, Z., Chen, L., Li, H. and Zhang, W. (2017a) 'Design and Implementation of an energy-efficient blockchain-based smart home for an aging Facebook', *Future Generation Computer Systems*, Vol. 75, No. 0167-739X, pp.424–432.
- Li, X., Jiang, P., Chen, T., Luo, X. and Wen, Q. (2017b) 'A survey on the security of blockchain systems', *Future Generation Computer Systems*, DOI: 10.1016/j.future.2017.08.020.
- Mougayar, W. (2016) *The Business Blockchain: Promise, Practice, and Application of the Next Internet Technology*, Wiley, Hoboken, New Jersey.

- Notheisen, B., Florian, H. and Weinhardt, C. (2017) 'Breaking down the blockchain hype – towards a blockchain market engineering approach', in *Proceedings of the 25th European Conference on Information Systems (ECIS)*, Guimarães, Portugal, 5–10 June, pp.1062–1080, ISBN 978-989-20-7655-3 Research Papers [online] http://aisel.aisnet.org/ecis2017_rp/69.
- O'Reilly, T. (2005) *What Is Web 2.0: Design Patterns and Business Models for the Next Generation of Software*, O'Reilly Media, Sebastopol (CA), USA.
- P2P FOUNDATION Contributors (2023) 'Web 3.0,' *P2P Foundation* [online] https://wiki.p2p.foundation.net/index.php?title=Web_3.0&oldid=36230 (accessed December 5, 2023).
- Qin, R. et al. (2023) 'Web3-based decentralized autonomous organizations and operations: architectures, models, and mechanisms', in *IEEE Transactions on Systems, Man, and Cybernetics: Systems*, April, Vol. 53, No. 4, pp.2073–2082, DOI: 10.1109/TSMC.2022.3228530.
- Quinn, D., Chen, L. and Mulvenna, M. (2013) 'Discovering social behaviour variances of younger and older users through social interaction analysis', *Int. J. of Web Science*, Vol. 2. Pp.44–65, DOI: 10.1504/IJWS.2013.056574.
- Ritzer G. (2019) *The Wiley Blackwell Encyclopedia of Sociology*, John Wiley & Sons, DOI: 10.1002/9781405165518.
- Söllner, M. and Leimeister, J.M. (2016) 'Decentralized systems in the age of Web 3.0', *Communications of the Association for Information Systems*, Vol. 39, No. 1, pp.13–38.
- Swan, M. (2015) *Blockchain: Blueprint for a New Economy*, O'Reilly Media, Inc., Sebastopol.
- Tapscott, D. and Tapscott, A. (2016) *Blockchain Revolution: How the Technology Behind Bitcoin Is Changing Money, Business, and the World*, Penguin Random House, New York, NY, USA.
- Veeramani, K. and Jaganathan, S. (2019) 'A quick synopsis of blockchain technology', *International Journal of Blockchains and Cryptocurrencies*, Vol. 1, p.54, DOI: 10.1504/IJBC.2019.101852.
- Wu, J., Lin, K., Lin, D., Zheng, Z., Huang, H. and Zheng, Z. (2022) 'Financial crimes in Web3-empowered metaverse: taxonomy, countermeasures, and opportunities', DOI: 10.48550/arXiv.2212.13452.
- Zeng, D.D., Chen, H., Lusch, R. and Li, S-H. (2011) 'Social media analytics and intelligence', *Intelligent Systems, IEEE*, Vol. 25, pp.13–16, DOI: 10.1109/MIS.2010.151.