Building a Stronger Foundation for Web3: Advantages of 5G Infrastructure

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Abstract: The emergence of Web3 technologies promises to revolutionize the Internet and redefine our interactions with digital assets and applications. This essay explores the pivotal role of 5G infrastructure in bolstering the growth and potential of Web3. By focusing on several crucial aspects—network speed, edge computing, network capacity, security and power consumption—we shed light on how 5G technology offers a robust and transformative foundation for the decentralized future of the Internet. Prior to delving into the specifics, we undertake a technical review of the historical progression and development of Internet and telecommunication technologies.

Keywords: Web3; 5G; blockchain; decentralized application; infrastructure

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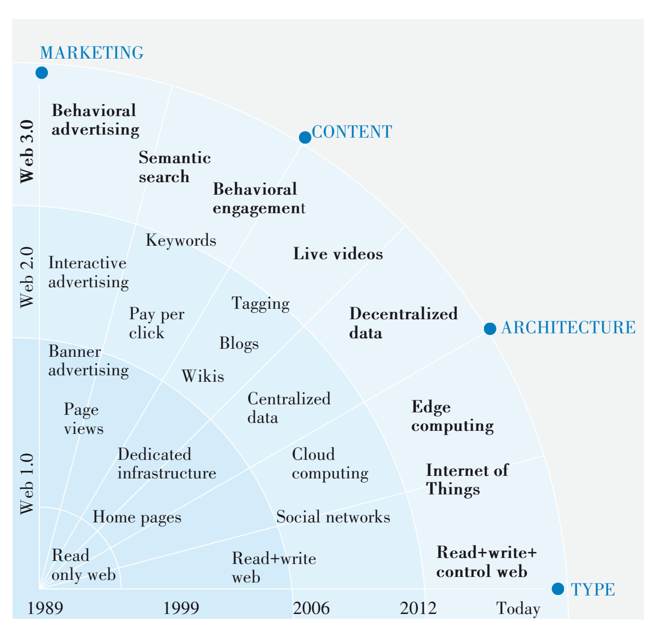
1 Introduction: The Web3 Revolution

Web3, also known as the decentralized web, presents a paradigm shift from its predecessor, Web2, by leveraging blockchain and other distributed ledger technologies (Fig. 1). This transformation envisions a more equitable, secure, and autonomous Internet where users regain control over their data, applications, and digital identities. However, achieving the full potential of Web3 requires a robust infrastructure, and herein lies the significance of 5G technology. The well-known Blockchain Trilemma emphasizes that within a decentralized system, attaining two out of the three core benefits—decentralization, security, and scalability—becomes feasible at any given point. In order to maintain uniform data coherence and the current state across all nodes within decentralized systems, diverse consensus algorithms are implemented, serving as the foundational support for both Layer 1 and Layer 2 infrastructures. When practical Web3 applications adopt a consistent consensus algorithm, their responsibility revolves around effectively managing the fundamental logic intrinsic to smart contracts and blockchains. The rapid advancements and widespread deployment of 5G are instrumental in overcoming critical challenges faced by Web3 applications, such as low transactions per second (TPS) and scalability. This essay delves into the advantages of 5G infrastructure in supporting the growth of Web3, focusing on network speed, edge computing, network capacity, security, and power consumption.[1 – 7]



▲ **Figure 1. Evolution and technologies of Web 1.0, Web 2.0 and Web 3.0 scenarios**

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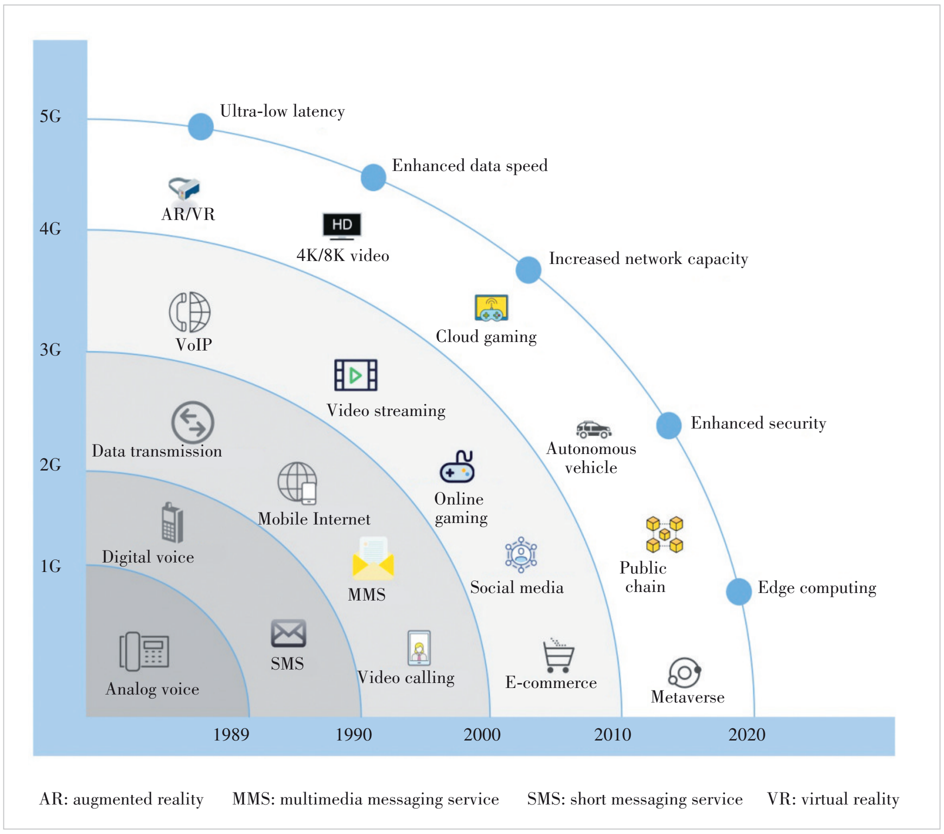
2 Network Speed: Paving the Way for Real-Time Interactions

Significant advancements in 5G technology have reduced latency from tens of milliseconds experienced in 4G to just a few milliseconds in 5G (Fig. 2). This reduction has enabled several novel application scenarios that were previously infeasible.[8]

Web3 applications heavily rely on real-time interactions, where decentralized finance (DeFi), metaverse, and augmented reality/virtual reality (AR/VR) demand seamless and instant communications. The discourse surrounding Web3 applications can be effectively divided into three primary components: frontend, backend, and smart contracts. In the context of frontend and backend aspects, it is crucial to acknowledge that the functioning of all Web3 applications is in, herently reliant on the direct integration of 5G technology and its accompanying high-speed network capabilities. 5G technology exhibits unparalleled network speeds that significantly reduce latency and boost data transfer rates. On the smart contract side, the operational speed of decentralized applications (dApps) hinges upon the efficiency of the underlying blockchain system. The synchronization of data across distinct nodes demonstrates a direct correlation with the swiftness of the 5G network, although this calculation must also encompass the impact of the chosen consensus algorithm. While blockchain infrastructures based on Proof of Work (PoW) may experience modest enhancements, it is noteworthy that Proof of Stake (PoS) mechanisms showcase substantial improvements. Leveraging the ultra-low latency of 5G, dApps built upon PoS frameworks, and encompassing both Layer 1 and Layer 2 infrastructures are poised to execute smart contracts with heightened efficiency. This augmentation in operational efficiency not only bolsters the responsiveness of DeFi protocols but also facilitates seamless user experiences, removing unnecessary friction. Furthermore, the increased bandwidth of 5G networks enables higher quality AR/VR experiences, empowering users with immersive and engaging content. In essence, 5G lays the groundwork for a seamless real-time Web3 experience.

The data in Table 1 depicts selected Web3 scenarios that may gain advantages from leveraging the 5G network, contingent upon precise implementation and the maturity levels of the



▲ **Figure 2. Historical progression of telecommunication networks from the 1st to 5th generation, showcasing various technologies and scenarios**

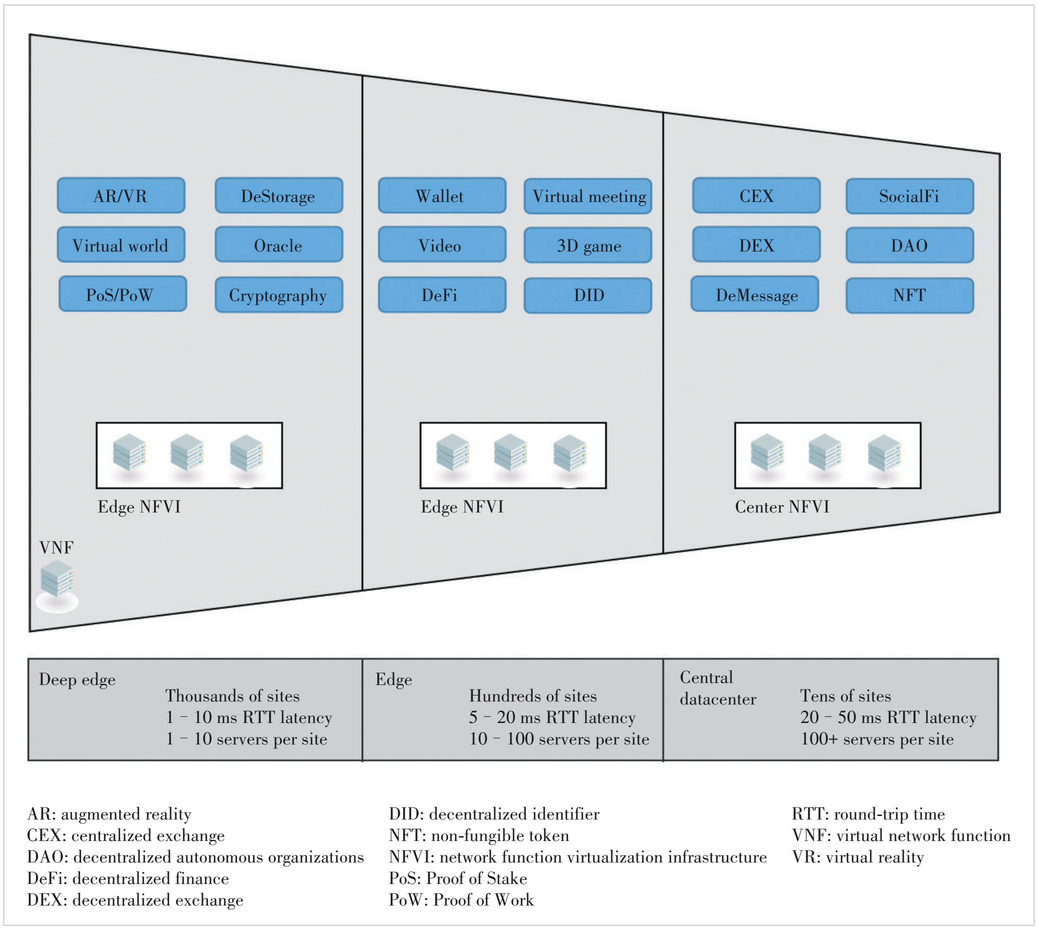
▼**Table1. Comparison of network speed, latency and related scenarios between 4G and 5G**

Network Generation	Speed (real world)	Speed (theoretical)	Latency (real world)	Latency (theoretical)	Supported Scenarios
4G	10 – 50 Mbit/s	300 Mbit/s	30 – 50 ms	10 ms	Video streaming Real-time gaming IoT applications Smart homes
5G	100 Mbit/s – 1 Gbit/s	10 Gbit/s	10 – 20 ms	1 ms	8K video streaming AR/VR dApps More efficient public chain X-to-earn games 3D virtual world

AR: augmented reality　dAPP: decentralized applications　VR: virtual reality underlying technology and applications. As Web3 and 5G technologies continue to evolve, more innovative use cases may emerge that take full advantage of 5G's speed and low latency.

3 Edge Computing: Empowering Distributed Applications

Multi-access edge computing (also known as mobile edge computing, MEC) is a critical feature of 5G networks. It is designed on a universal X86 platform, which transforms every 5G base station into a powerful edge computing node. Unlike today's cloud computing providers that deploy dozens of data centers around the world, 5G deployment will rapidly expand the scale of data centers to millions. Certain Web3 applications are constructed and evaluated within consortium or private blockchain settings. The comprehensive development lifecycle can be significantly fortified through the integration of edge computing. For instance, a cluster of MEC devices can swiftly establish a blockchain infrastructure. This approach offers expedient means to develop and test Web3 applications within this environment.



▲Figure 3. Various scenarios operating at different positions and distances with the 5G network

The decentralization of Web3 applications often means distributing computing power and resources across a network of nodes. Here, edge computing becomes a game-changer. 5G's edge computing capabilities facilitate the processing and storage of data closer to the end-users, reducing latency and enhancing the efficiency of distributed applications (Fig. 3). By leveraging edge servers, Web3 dApps can provide a smoother user experience, enhanced privacy, and reduced reliance on centralized data centers. This integration of 5G and edge computing fosters a more robust, scalable, and responsive Web3 ecosystem.[9–12]

4 Network Capacity: Facilitating Mass Adoption of Web3

The network capacity of 5G has been greatly improved, with over 20 times the capacity of 4G, thanks to the deployment of a large number of micro base stations.

The mass adoption of Web3 technologies necessitates a network capable of handling an ever-increasing number of connected devices and transactions. Given that numerous decentralized nodes operate on distinct cloud servers, the synchronization of data within the decentralized system is intricately linked to the capacity of the network. The decentralized and distributed nature of Web3 networks and applications presents very high requirements and challenges for the underlying basic communication network bandwidth and capacity. Hundreds of millions or even billions of terminals are constantly synchronizing and communicating with each other, and once network congestion occurs, it could lead to huge disasters. Traditional networks may struggle to cope with the projected surge in demand. 5G, with its unprecedented network capacity, emerges as the ideal solution. With its higher frequencies, smaller cells, and advanced beamforming techniques, 5G networks can accommodate a vast number of connected devices simultaneously. This scalability is crucial for ensuring the seamless functioning of Web3 applications, supporting the growth of the Internet of Things (IoT) and enabling widespread adoption.[13–14]

5 Security: Safeguarding the Decentralized Web

5G networks offer several advantages in terms of security, as shown in Table 2. With enhanced encryption, users can be assured of secure transmission of data. Additionally, 5G networks are designed to have a more secure architecture, making it more difficult for hackers to breach the network. The use of virtualized network functions in 5G networks also enables more advanced security features such as network slicing and isolation, which can help protect against cyber attacks.[15–16]

The decentralized nature of Web3 applications already brings inherent security benefits compared to centralized counterparts. Nevertheless, ensuring data integrity, user privacy, and protection against cyber threats remains paramount. 5G's enhanced security features, such as end-to-end encryption and network slicing, bolster the defenses of Web3 applications. Network slicing enables isolation and dedicated resources for specific services, reducing the attack surface and enhancing the resilience of decentralized networks. Additionally, the use of virtual private networks (VPNs) and enhanced authentication mechanisms in 5G further enhances the security and trustworthiness of Web3 systems.

6 Power Consumption: Enhancing Sustainability and Eco-Friendly Practices in Web3 Development

The power consumption dynamics of 5G networks exhibit a notable advantage over their 4G counterparts, primarily attributed to the incorporation of advanced radio access technologies, network virtualization, and sophisticated signal processing techniques.

Based on the research conducted by Nokia, the unit traffic power consumption for 5G technology exhibits significant efficiency gains over traditional technologies, reducing to as low as 10% of the previous energy consumption levels. This enhanced power efficiency becomes of paramount importance within the Web3 industry, as developers and practitioners grapple with the challenge of addressing criticisms regarding power consumption associated with decentralized applications. Particularly, blockchain-based Web3 applications have faced scrutiny due to the energy-intensive consensus mechanisms utilized for transaction validation. In this context, the low-power attributes of 5G technology offer a promising solution, optimizing the allocation of network resources and minimizing energy wastage. By reducing the energy requirements for data transmission and processing, 5G effectively mitigates the environmental impact of Web3 applications, fostering a more sustainable and eco-friendly digital ecosystem. This proactive, environmentally-conscious approach not only addresses concerns related to excessive power consumption but also positions Web3 at the forefront of advocating energy-efficient and eco-conscious technologies for the future.

The data presented in Table 3 indicates a substantial improvement in energy for data transmission (dozens of times), which is expected to considerably reduce energy consumption and mitigate the environment impact of Web3 industry.

7 Case Study: 5G Powers Web3 Application in Real World

The indispensability of graphics processing units (GPUs) across domains such as blockchain, artificial intelligence (AI),

▼Table 2. Comparison of security features and related scenarios between 4G and 5G

Network Generation	Security Features	Supported Scenarios
4G	Basic encryption (AED-128) Subscriber identity module authentication Authentication and Key Agreement (AKA)	Mobile broadband, web browsing Online gaming, basic applications Moderate user density
5G	Enhanced encryption (AES-256) Stronger mutual authentication Improved integrity protection Network slicing for isolated security domains Certificate-based device authentication Enhanced privacy protection (5G AKA) Improved authentication protocols (5G-EAP) Enhanced security for IoT devices (5G-SBA)	Augmented reality (AR) and virtual reality (VR) DeFi /GameFi / SocialFi / Wallet / NFT Public chain (PoS / PoW) Virtual world / Metaverse Massive IoT deployment Ultra-high user density Mission-critical communications

▼Table 3. Comparison of energy, network capacity, energy efficiency and related scenarios between 4G and 5G

Network Generation	MIMO	Energy/Watt	Capacity/(Mbit/s)	Energy Efficiency/(GB/kW·h)	Supported Scenarios
4G	2T2R	400	150	165	-
	4T4R	685	300	192	
5G	32T32R	500	5 000	4 395	Scenarios involving extensive wireless communications (Public chain, Metaverse, GameFi, ...)
	64T64R	810	10 000	5 425	

rendering, gaming, and data science is widely acknowledged. However, the contemporary GPU resource landscape is constrained by limitations in availability and exorbitant costs. In this context, we present a practical use case elucidating how the convergence of 5G technology and Web3 principles is poised to revolutionize GPU resource utilization within the rendering industry.

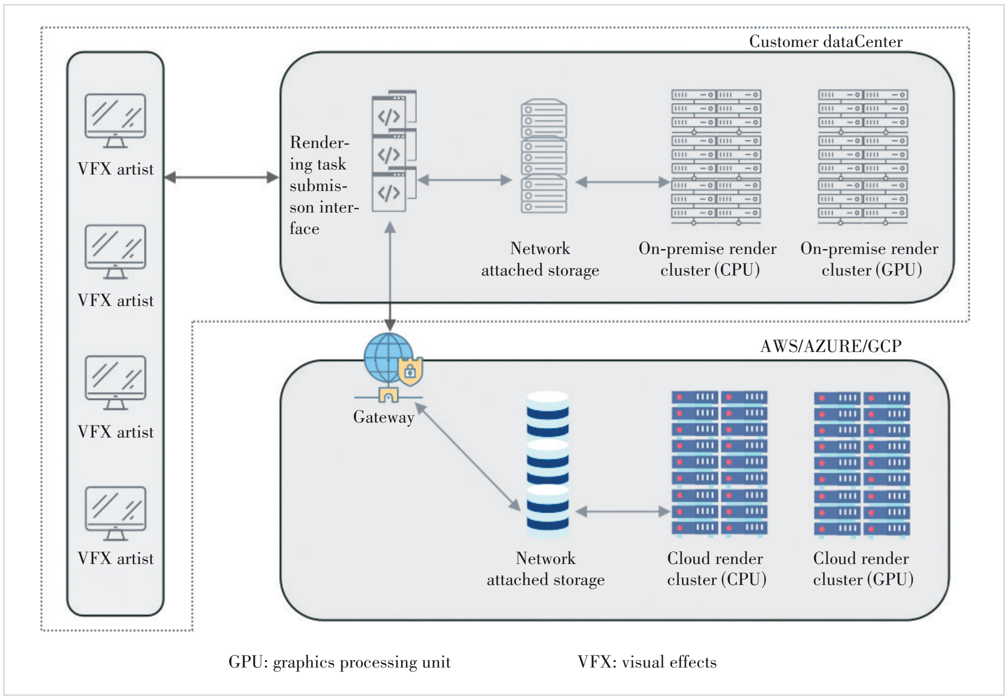
Launched in 2017, the Render Network serves as an intricate framework designed to cater to a diverse spectrum of computational tasks, ranging from fundamental rendering operations to intricate artificial intelligence processes. These tasks are expedited with remarkable speed and efficiency within a blockchain-driven peer-to-peer network, characterized by its resolute immunity to errors and delays, and fortified by airtight property rights protection.

Pioneering an epochal advancement, the Render Network stands as the pioneering decentralized GPU rendering platform. This pioneering platform endows artists with the capability to dynamically scale GPU rendering workloads on-demand, orchestrating them across globally distributed high-performance GPU Nodes. By virtue of an intricately designed blockchain marketplace tailored to harness latent GPU compute capacities, artists are endowed with unparalleled prowess to amplify their next-generation rendering endeavors. This decentralized architectural paradigm fosters a transformative departure from the conventional centralized GPU cloud model, heralding a realm of cost-efficiency and an astronomical surge in computational acceleration, upending established norms.[17–20]

A comparative analysis between the traditional rendering methodology and the decentralized distributed approach is shown in Table 4, Figs. 4 and 5.

In addition to the paradigm illustrated by the Render Network, a plethora of analogous Web3 applications have demonstrated advantageous integration with the burgeoning 5G network infrastructure. Noteworthy examples encompass Caduceus, Portalverse, Ipolloverse, and DBChain, each exhibiting symbiotic relationships with 5G, thereby enhancing their operational efficiency and user experiences.

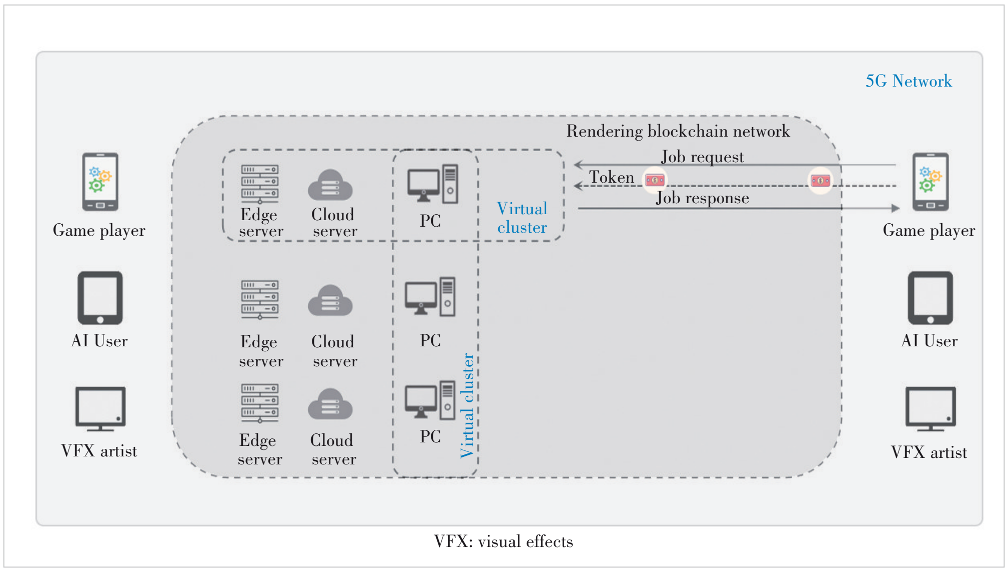
Concurrently, the synergy between blockchain and 5G unveils profound implications. Evidently, the Helium project emerges as an exemplar in leveraging blockchain technology to amplify the ambit of 5G coverage. By harnessing blockchain's innate attributes, Helium extends the perimeter of 5G accessibility, facilitating broader and more inclusive participation within the 5G ecosystem. This confluence exemplifies the potent interplay between blockchain's decentralized architecture and the transformative potential of 5G networks.



▲ **Figure 4. Conventional rendering approach involving on-premise data centers or remote centralized cloud services.**

▼**Table 4. What 5G network and technologies can bring to various rendering approaches**

Rendering Approach	5G Network & Technologies	Advantages	Disadvantages
Centralized on-premise cloud (AWS etc.)	Not needed	Complete authority over resource security is assured	Expensive resource Low utilization Less scalability Costly maintaining
Decentralized distributed	Ultra-low latency High speed transmission Network capacity Network security	Flexible scalability High utilization rate Efficient infrastructure Cost effective Almost unlimited resource	Security is uncertain uncontrolled resource



▲ **Figure 5. Innovative paradigm facilitated by 5G networks, enabling end-users to seamlessly access available resources from any location and at any time**

8 Future Challenges: Web3 Necessitating 5G and Upcoming Advancements

1) Latency and bandwidth requirements

Web3 applications relying on real-time data processing and interactions impose stringent demands for ultra-low latency and high bandwidth. While 5G edge computing mitigates latency, specific use cases may necessitate even lower latency and higher bandwidth. Emerging metaverse platforms like Decentraland, Sandbox, and Roblox witness rapid popularity and attract substantial user bases. Both Decentraland and Sandbox enjoy advantages stemming from their seamless frontend experiences and their utilization of smart contracts and NFTs to safeguard users' assets within decentralized systems. Moreover, multichain metaverses such as Matrix World stand to gain even greater benefits from the rapid expansion of 5G networks. Cloud-based metaverses offer players a seamless virtual world experience through their frictionless multichain connectivity, further augmented by the growth of 5G technology. According to a recent Gartner study, by 2026, 25% of the global population is projected to spend at least one hour daily in the metaverse, engaging in activities like work, shopping, education, social interactions, and entertainment. These virtual worlds simulate reality using 3D, 4K/8K video streaming, and real-time interactions, demanding heavy traffic and ultra-low latency, requirements that current 5G networks may not fully meet. To address these challenges, future technologies, such as Terahertz (THz) communication or advanced photonics, hold the potential to significantly enhance data transfer rates and minimize latency, thereby ensuring seamless user experiences in the metaverse.[21–22]

2) Security and data integrity

Decentralized applications are vulnerable to security breaches and data tampering. Blockchain consensus mechanisms involve a substantial number of participants, whether utilizing PoS or PoW. In theory, a higher number of participants in the blockchain network contribute to enhanced safety and security. This relies on the assumption that the participants are controlled by independent and separate entities. Presently, Ethereum has approximately half a million validators, with a significant portion running on cloud platforms like AWS, Azure, and GCP. This setup raises concerns, as cloud providers potentially hold the ability to influence the blockchain under specific conditions. With the advent of 5G, the abundance of edge devices surpasses the current cloud providers. In the near future, a considerable portion of nodes running on edge devices will be controlled by network operators. Overcoming and eliminating these security concerns presents a significant technical challenge in ensuring the integrity and trustworthiness of blockchain systems. To address these challenges, future technologies might include robust encryption methods, quantum-resistant cryptography, and blockchain-based consensus mechanisms that improve security and establish trust in the data exchanged between edge devices and the Web3 applications.

3) Interoperability and standards

Web3 applications often operate on multiple blockchain platforms and protocols, leading to challenges in achieving seamless interoperability among them. The increasing variety of blockchain types, present and future, deployed on 5G networks further adds to the complexity. Addressing seamless interoperability within the 5G network is another significant challenge due to the diverse technologies it encompasses, such as small cells, multiple-input multiple-output (MIMO), full duplex, and beamforming, each functioning differently. Interoperability holds a pivotal role within cross-chain technology. Effective data communication and the seamless transfer of assets across different chains necessitate the establishment of protocols and standards. These elements are crucial in unlocking the full potential of blockchain technology. Future technologies must prioritize establishing common standards and protocols to facilitate smooth communication and data exchange between various blockchains and networks. Emphasizing standardization will foster compatibility and enhance the overall Web3 ecosystem.

4) Edge infrastructure scalability

Edge computing relies on a distributed network of edge devices. Scalability becomes crucial as Web3 applications experience increased user adoption. Blockchain networks such as Bitcoin and Ethereum typically have the capacity to process dozens of TPS, whereas certain Layer-2 blockchain solutions like Polygon, Arbitrum, and Optimism can handle significantly higher TPS, reaching up to 65 000. The substantial TPS demands from numerous edge devices pose significant challenges to network scalability. Future technologies might involve advances in distributed computing, mesh networks, and software-defined infrastructures that can dynamically scale based on demand, ensuring optimal performance and availability.

5) Energy efficiency

In comparison to the previous generation, 5G technology demonstrates remarkable improvements in unit traffic power consumption, significantly lowering energy requirements. However, this efficiency gain comes at the cost of deploying a larger number of 5G base stations due to their limited coverage area. Additionally, the individual power consumption of 5G base stations is greater than that of 4G, leading to an overall increase in power consumption. Considering the projected growth of the blockchain industry and the potential for a significant number of blockchain nodes to run on 5G edge devices, network operators may face the challenge of deploying an even larger number of base stations to meet the burgeoning demand. To address this issue, solely focusing on reducing power consumption may not suffice, necessitating exploration of more feasible alternatives such as harnessing renewable energy sources like solar and wind energy. Integrating sustainable energy solutions can help mitigate the environmental impact and ensure the long-term sustainability of the 5G network infrastructure as it adapts to the evolving demands of the blockchain industry. Future technologies could include energy harvesting solutions, advanced power management techniques, and renewable energy integration to reduce the ecological footprint of edge computing operations.

6) Data governance and regulation

With the decentralized nature of Web3 applications and data processing at the edge, concerns about data governance and compliance with regulations might arise. 5G network operators retain sensitive customer information, encompassing personal and identification details like credit card data, address details, wallet information, transaction records, and payment history. In light of regulations like General Data Protection Regulation (GDPR), privacy demands have intensified, emphasizing robust user data protection and granting users greater control and ownership over their data. As data stored and recorded on a blockchain is immutable by design, it cannot be deleted or forgotten, ensuring data permanence and integrity. Future technologies could incorporate self-sovereign identity solutions, decentralized data marketplaces, and AI-driven compliance frameworks to address these challenges while empowering users with control over their data.

7) Reliability and fault tolerance

Token property holds a critical role within the Web3 ecosystem, where a plethora of applications such as DeFi, GameFi, and SocialFi heavily rely on token finance. Ensuring utmost reliability and robustness in the infrastructure network becomes imperative for these applications. While 5G networks have made significant strides in enhancing resilience through network slicing and dynamic rerouting, their susceptibility to signal degradation and limited coverage due to high-frequency signals poses challenges, leading to dropped connections and reduced reliability in specific regions. However, with the imminent arrival of 6G, the landscape of communication technology is set to witness groundbreaking advancements in ultra-reliable and fault-tolerant communications. Leveraging improved beamforming and massive MIMO technologies, 6G networks are poised to transcend the coverage limitations faced by 5G, promising more consistent connectivity across diverse environments. Furthermore, 6G is anticipated to implement sophisticated fault-tolerance mechanisms capable of autonomous self-healing and real-time network reconfiguration. By amalgamating resilient consensus mechanisms, redundant edge nodes, and decentralized storage solutions, a seamless and uninterrupted access to Web3 applications can be confidently expected.[23–24]

Addressing these challenges will require collaborative efforts from technology developers, industry stakeholders, and regulatory bodies. By leveraging future technologies that focus on performance, security, and user experience, Web3 applications can realize their full potential while leveraging the benefits of 5G advantages. It is essential to continuously innovate and adapt to the evolving landscape to build a robust and sustainable Web3 ecosystem.

9 Conclusion: Symbiotic Future of 5G and Web3, Unleashing a Full Potential of the Decentralized Web

In conclusion, the seamless integration of 5G infrastructure into the Web3 ecosystem holds the key to the success and widespread adoption of decentralized technologies. The remarkable combination of unparalleled network speed, advanced edge computing capabilities, expansive network capacity, robust security features, and energy-efficient low-power consumption provides a robust foundation for the decentralized web to flourish. As we embark on a path towards a more autonomous, equitable, and decentralized Internet, the convergence of 5G and Web3 forges a symbiotic relationship that unlocks the full potential of the decentralized web, fundamentally transforming the way we interact with digital assets and applications in the future. This transformation will revolutionize industries, redefine financial systems, empower individuals, and democratize access to information and opportunities.

The ongoing development and optimization of 5G networks are indispensable in building a stronger foundation for Web3 and fulfilling the promise of a decentralized, secure, sustainable, and user-centric digital world. As the world continues to embrace this symbiotic future, the decentralized web will stand as a beacon of innovation, trust, transparency, and inclusivity, paving the way for an unparalleled landscape of opportunities and a more equitable and transformative digital future.[25]

References

[1] MURRAY A, KIM D, COMBS J. The promise of a decentralized Internet: what is Web3 and how can firms prepare? [J]. Business horizons, 2023, 66 (2): 191 – 202. DOI: 10.1016/j.bushor.2022.06.002
[2] LI H, DANG R R, YAO Y, et al. A review of approaches for detecting vulnerabilities in smart contracts within web 3.0 applications [J]. Blockchains, 2023, 1(1): 3 – 18. DOI: 10.3390/blockchains1010002
[3] SADOWSKI J, BEEGLE K. Expansive and extractive network of Web3 [J]. Big data & Society, 2023, 10(1): 1 – 14. DOI: 10.1177/20539517231159629
[4] JIN L, PARROTT K. Web3 is our chance to make a better internet [J]. Harvard business review, 2022
[5] Goldman Sachs. Framing the Future of Web3.0 [R]. 2021
[6] A16z. The Web3 Landscape [R]. 2021
[7] CHAER A, SALAH K, LIMA C, et al. Blockchain for 5G: opportunities and challenges [C]//Globecom Workshops. IEEE, 2019. DOI: 10.1109/GCWkshps45667.2019.9024627
[8] NORP T. 5G requirements and key performance indicators [J]. Journal of ICT standardization, 2018, 6(1): 15 – 30. DOI: 10.13052/jicts2245-800x.612
[9] WANG H, LI H, SMAHI A, et al. MIS: a multi-identifier management and resolution system in the metaverse [J]. ACM transactions on multimedia computing, communications, and applications, 2024, 20(7): 191. DOI: 10.1145/3597641
[10] Ericsson. Edge computing and 5G [R]. 2020
[11] SIRIWARDHANA Y, PORAMBAGE P, LIYANAGE M, et al. A survey on mobile augmented reality with 5G mobile edge computing: architectures, applications, and technical aspects [J]. IEEE communications surveys & tutorials, 2021, 23(2): 1160 – 1192. DOI: 10.1109/comst.2021.3061981
[12] NABBEN K. Decentralised autonomous organisations (DAOs) as data trusts: a general-purpose data governance framework for decentralised data ownership, storage, and utilization [J]. Social science research network, 2021. DOI: 10.2139/ssrn.4009205
[13] China Mobile, China Telecom, China Unicom, et al. 5G-advanced technology evolution from a network perspective: towards a new era of intelligent connect X [R]. 2021
[14] MODESTA E E, FRANCIS A O, ANTHONY O O. A framework of 5G networks as the foundation for IoTs technology for improved future network [J]. International journal of physical sciences, 2019, 14(10): 97 – 107. DOI: 10.5897/ijps2018.4782
[15] GUPTA R K, ALMUZAINI K K, PATERIYA R K, et al. An improved secure key generation using enhanced identity-based encryption for cloud computing in large-scale 5G [J]. Wireless communications and mobile computing, 2022: 7291250. DOI: 10.1155/2022/7291250
[16] FROEHLICH M, WALTENBERGER F, TROTTER L, et al. Blockchain and cryptocurrency in human computer interaction: a systematic literature review and research agenda [C]//Proc. Designing Interactive Systems Conference. ACM, 2022: 155-177. DOI: 10.1145/3532106.3533478
[17] SUDHAMANI C, ROSLEE M, TIANG J J, et al. A survey on 5G coverage improvement techniques: issues and future challenges [J]. Sensors, 2023, 23(4): 2356. DOI: 10.3390/s23042356
[18] TAKYAR A. Web3 use cases and applications [EB/OL]. [2024-01-15]. https://www.leewayhertz.com/web3-use-cases-and-applications
[19] GOEL A K, BAKSSHI R, AGRAWA K K. Web3.0 and decentralized applications [C]//2nd International Conference on Innovative Research in Renewable Energy Technologies (IRRET 2022). IMPS, 2022. DOI: 10.3390/materproc2022010008
[20] ALLEN D, FRANKEL E, LIM W, et al. Ethics of decentralized social technologies: lessons from Web3, the fediverse, and beyond [R]. 2023
[21] MCCORMICK P. The value chain of the open metaverse [EB/OL]. (2021-01-25) [2024-01-15]. https://www. notboring. co/p/the-value-chain-of-the-open-metaverse
[22] Citi GPS. Metaverse and money: decrypting the future [R]. 2022
[23] Protocol Labs. Filecoin: a decentralized storage network [R]. 2018
[24] Storj. Storj: decentralized cloud storage [R]. 2017
[25] RAGNEDDA M, DESTEFANIS G. Blockchain and Web3.0: social, economic, and technological challenges [M]. UK: Taylor & Francis, 2019. DOI: 10.4324/9780429029530

Biographies

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