Asia Pacific Academy of Science Pte. Ltd.

Metaverse 2025, 6(1), 3232.
https://doi.org/10.54517/m3232

Article

Society 5.0 in the cloud: Harnessing the power of modern information technologies

Yasaman Ghaderi[1], Mohammad Reza Ghaderi[2,*]

[1] Tarbiat Modares University, Tehran 14115111, Iran
[2] Islamic Azad University, South Tehran Branch, Tehran 1584743311, Iran
*** Corresponding author:** Mohammad Reza Ghaderi, st_mr_ghaderi@azad.ac.ir

CITATION

Ghaderi Y, Ghaderi MR. Society 5.0 in the cloud: Harnessing the power of modern information technologies. Metaverse. 2025; 6(1): 3232. https://doi.org/10.54517/m3232

ARTICLE INFO

Received: 21 January 2025
Accepted: 12 February 2025
Available online: 27 February 2025

Abstract: In the rapidly evolving technological landscape, modern innovations such as blockchain (BC), artificial intelligence (AI), and the Internet of Things (IoT) are playing a pivotal role in realizing the vision of Society 5.0. This concept envisions a harmonious integration of physical, digital, and human elements to create a sustainable and progressive future. Emerging technologies like robotics, biotechnology, quantum computing, 5G/6G networks, smart cities, and the metaverse are expected to further amplify the impact of Society 5.0, driving transformative changes across industries and societal structures. The integration of BC, AI, and IoT within cloud-based frameworks offers a robust solution to enhance security, privacy, and data management. The integration of blockchain, AI, and IoT within a cloud-based framework offers a transformative solution to address the challenges of modern societies. By leveraging these technologies, the proposed platform aims to create a secure, efficient, and sustainable ecosystem that enhances quality of life and drives progress toward the vision of Society 5.0. This approach not only tackles current societal issues but also paves the way for a more interconnected and innovative future. This article introduces a platform that seamlessly combines these technologies to provide a secure and reliable foundation for data collection, sharing, and analysis while enabling the development of smart applications that improve efficiency, productivity, and overall quality of life (QoL).

Keywords: artificial intelligence; cloud computing; blockchain; internet of things; society 5.0

1. Introduction

The rapid evolution of digital technologies has ushered in a new era of societal transformation, with Society 5.0 emerging as a visionary framework for addressing complex global challenges. While technological advancements such as artificial intelligence (AI), blockchain (BC), the Internet of Things (IoT), and cloud computing (CC) have individually demonstrated significant potential, their synergistic integration offers unprecedented opportunities to create innovative solutions for the next-generation society. However, despite the growing body of research on these technologies, there remains a critical gap in understanding how their convergence can be harnessed to build a unified platform that addresses the pressing needs of Society 5.0.

This paper introduces an innovative platform that integrates AI, BC, IoT, and CC to tackle key challenges in Society 5.0, such as enhancing connectivity, automation, efficiency, sustainability, inclusivity, and well-being. The motivation behind this research stems from the need to bridge the gap between technological advancements and their practical application in solving real-world problems. By leveraging the

complementary strengths of these technologies, the proposed platform aims to create new value, enable unique applications, and foster a more sustainable and inclusive future. The primary objectives of this paper are threefold:

1) To explore the potential of integrating AI, BC, IoT, and CC in addressing the challenges of Society 5.0.
2) To introduce a novel platform that leverages this integration to create innovative solutions.
3) To discuss the implications, challenges, and opportunities associated with the platform's implementation and adoption.

The research questions guiding this study are:

- How can the integration of AI, BC, IoT, and CC address the challenges of Society 5.0?
- What are the key features and capabilities of the proposed platform?
- What are the potential barriers and opportunities in implementing this platform?

The remainder of this paper is structured as follows: Section 2 provides preliminaries and related works of the studies on the integration of AI, BC, IoT, and CC, highlighting their contributions to Society 5.0. Section 3 introduces the proposed platform, detailing its architecture, functionalities, and potential impact. Section 4 discusses the challenges and opportunities associated with the platform, including barriers to adoption and future directions. Finally, Section 5 concludes the paper by summarizing the key findings and their implications for Society 5.0.

2. Preliminaries and related works

2.1. Preliminaries

2.1.1. Society 5.0

The evolution of future societies is being driven by digital innovations, shaped by rapid technological advancements, shifting demographics, and changing social norms. This new era is marked by heightened connectivity, cultural diversity, and groundbreaking technological progress, offering both opportunities and challenges Bublitz [1]. Society 5.0, a concept pioneered in Japan, represents the next phase of societal development, emphasizing the integration of cyber and physical systems to create a sustainable, inclusive, and human-centric ecosystem. This vision leverages cutting-edge technologies such as artificial intelligence (AI), robotics, and the Internet of Things (IoT) to tackle social issues and improve quality of life. For instance, advanced healthcare systems utilizing AI and remote monitoring are enhancing health outcomes while reducing costs [2].

Within Society 5.0, smart transportation and energy systems are being developed to address challenges like traffic congestion, safety concerns, and energy inefficiency. These innovations aim to create more efficient and sustainable urban environments. Following the era of Industry 4.0, which focused on automation and data exchange in manufacturing, Industry 5.0 is emerging as a human-centered approach to production. This new phase emphasizes the collaboration between humans and advanced technologies, such as AI, robotics, and IoT, to foster creativity, innovation, and inclusivity in manufacturing [3]. Industry 5.0 prioritizes creating responsive, flexible,

and customer-aligned production environments. A key aspect of this paradigm is co-creation, where humans and machines work together in design and manufacturing processes. Unlike traditional automation, where machines simply execute tasks, Industry 5.0 envisions machines as active participants in creative problem-solving, working alongside humans to develop innovative solutions. This collaborative approach not only enhances efficiency but also drives innovation by combining human ingenuity with machine precision.

Sustainability and social responsibility are central to Industry 5.0, urging manufacturers to minimize their environmental impact. This includes reducing waste, conserving resources, and adopting eco-friendly practices. By prioritizing sustainability, Industry 5.0 contributes to a greener future while strengthening corporate social responsibility within the manufacturing sector [4]. In summary, Society 5.0 and Industry 5.0 represent transformative shifts toward a more connected, inclusive, and sustainable future. By integrating advanced technologies with human creativity and prioritizing sustainability, these paradigms aim to address societal challenges while fostering innovation and improving quality of life.

2.1.2. Transition from current society to society 5.0

Current society technologies

Our modern society is faced with a multitude of innovations, and we explore some of these significant advancements:

- AI: Artificial intelligence has made a profound impact across various sectors, including healthcare, finance, and transportation. Its applications range from diagnosing medical conditions to optimizing supply chain management [5].
- BC: Blockchain technology is another transformative innovation that ensures secure and transparent transactions in industries such as finance, healthcare, and supply chain management. This technology has the potential to fundamentally change how data is managed and transactions are conducted, leading to significant improvements in these processes [6].
- VR & AR: Virtual Reality (VR) and Augmented Reality (AR) technologies play a vital role in several fields, including gaming, education, and healthcare. They provide immersive experiences that enhance learning outcomes and foster innovation and engagement within these sectors [7].
- 3D printing: The advent of 3D printing technology allows for the creation of complex objects from a variety of materials, including plastics and metals. This innovation is making waves in industries like healthcare, aerospace, and architecture, transforming production methods and material usage for greater efficiency and creativity [8].
- Electric vehicles: Electric vehicles (EVs) are increasingly popular as they present a more environmentally friendly alternative to traditional gasoline-powered cars. Advances in technology have made EVs more affordable and practical, offering longer driving ranges and quicker charging times [9].
- Biotechnology: Biotechnology is essential for developing innovative treatments for diseases, improving crop yields, and creating sustainable materials. This multifaceted field has the potential to transform numerous industries and significantly enhance our quality of life. By leveraging biotechnology, we can

strive for a healthier and more sustainable future for generations to come [10].

- Renewable energies: Renewable energy sources, such as solar, wind, and hydropower, are becoming increasingly affordable and accessible, providing viable alternatives to traditional fossil fuels. This transition not only reduces our reliance on non-renewable resources but also aids in combating climate change. By adopting sustainable energy solutions, we can safeguard the environment and pave the way for a greener, more sustainable future for future generations [11].

Society 5.0 technologies

The following anticipated innovations are expected to have a profound impact on the forthcoming Society 5.0:

- AI: Artificial intelligence is projected to evolve substantially, becoming more embedded in various facets of our daily lives within Society 5.0 [12].
- Robotics: The field of robotics is poised for significant advancements and diversification, with applications extending across multiple sectors, including healthcare, manufacturing, and agriculture. These robots will be engineered to perform tasks that are hazardous, complex, or repetitive for humans [13].
- Biotechnology: Biotechnology is anticipated to make further strides with breakthroughs in areas such as gene editing, regenerative medicine, and synthetic biology. These advancements will likely enhance human health, support environmental conservation, and facilitate the development of sustainable resources for a brighter future [14].
- Quantum Computing: Quantum computing (QC) possesses tremendous potential to revolutionize information processing and address complex problems, paving the way for significant advancements in sectors like drug discovery, finance, and cryptography. This cutting-edge technology could bring about transformative changes across various fields [15].
- 5G/6G Networks: The rollout of 5G and the forthcoming 6G networks are expected to provide ultra-fast, low-latency connectivity, essential for powering the next generation of advanced technologies, including AR, VR, smart cities, and autonomous vehicles [16].
- IoT: The Internet of Things (IoT) will continue to grow, linking different components of our environment, including homes, cities, and vehicles [17].
- Smart Cities: The development of smart cities is anticipated to increase in complexity, utilizing technologies such as IoT and AI, among other innovative solutions. These advancements aim to enhance sustainability, efficiency, and overall livability in urban settings [18].
- Metaverse: The relationship between the metaverse and Society 5.0 is generally aimed at improving the quality of life and productivity of humans in both the digital and physical worlds. The metaverse is a multidimensional virtual space in which users can interact, collaborate, and experience new things. This space provides opportunities to move from the real world to the digital world and vice versa. The metaverse can help create new digital communities and economic spaces in which people can participate in economic, artistic, and social activities. This can help diversify and expand jobs and offer new business models. Using the metaverse, connections between people beyond geographical boundaries are

possible. In Society 5.0, this capability can help improve social interactions and create a sense of community. The metaverse can improve the quality of life of people and help create more sustainable societies by providing tools for learning, entertainment, and social interactions.

This article aims to introduce an innovative platform that arises from the integration of four essential technologies: AI, blockchain (BC), IoT, and cloud computing (CC). This platform has the potential to generate new value, enable unique applications, and tackle challenges facing the next-generation society. It seeks to promote greater connectivity, automation, efficiency, sustainability, inclusivity, and well-being in our daily lives, work, and interactions with one another and our environment.

2.2. Related works

Numerous studies have explored the integration of various technologies within Society 5.0. In the research presented in [19], the authors emphasize significant advancements in information and communication technology (ICT), particularly highlighting the evolution of the Internet of Things (IoT) and its impact on sectors like finance, healthcare, transportation, education, and entertainment. While blockchain (BC) possesses considerable potential for driving technological innovation and industrial transformation, it also faces challenges such as high energy consumption, data redundancy, anomaly detection, smart contract efficiency, and management issues. To tackle these problems and enhance BC's performance, artificial intelligence (AI) can provide effective solutions, leading to a more secure, reliable, and efficient BC system. However, research on smart BC is still in its infancy, with many challenges yet to be resolved.

In the study cited in [20]. the authors examine the convergence of BC technology and AI as a unique catalyst for the development of smart and sustainable applications within the IoT. They introduce a digital analysis system that employs BC technology for storing results in decentralized cloud repositories, aiming to improve various applications. The research underscores the rapid advancements of AI-based technologies, such as machine learning and deep learning, which are crucial for extracting accurate information from extensive datasets. These AI methodologies hold significant promise for IoT applications, and when integrated with BC technology, they can transform smart city infrastructures, fostering sustainable ecosystems for IoT initiatives.

The authors of [21] highlight the importance of cloud computing (CC) in contemporary society, supporting a diverse array of applications from infrastructure to social media. To address the evolving demands of computing applications, they propose a conceptual model that investigates the impact of three emerging paradigms (BC, IoT, and AI) on the future of CC systems. This study presents a systematic review of computing paradigms and technologies, focusing on the combined influence of BC, IoT, and AI on the advancement of CC.

In the research referenced in [22], the authors focus on designing an IoT architecture that integrates BC and AI to facilitate efficient big data analysis. They propose a smart IoT architecture capable of BC integration with AI, effectively

merging these technologies for IoT applications by leveraging current techniques and existing systems. The qualitative evaluation in this paper discusses the integration of AI and BC in IoT applications through two perspectives: "BC based on AI" and "AI based on BC."

The study in [23] emphasizes the increasing emphasis on extracting knowledge from the vast amounts of raw data generated by the IoT, particularly due to the rapid growth of sensor-generated data. In the current CC architecture, all IoT data is sent to the cloud for processing, storage, and management. This work aims to draw attention to the importance of distributed information and its role in addressing current IoT challenges, including availability, mobility, energy efficiency, security, scalability, interoperability, and reliability. The authors stress the significance of distributed intelligence in IoT, as it supports precise processing and communication functions at specific times and locations, thereby enhancing overall efficiency and performance.

In [24], the authors discuss BC technology as a groundbreaking financial innovation that has the potential to transform business transactions. As a decentralized network incorporating various cryptographic models, BC ensures secure and flexible transactions. The integration of BC with CC aims to bolster trust among data servers, users, and data security. The authors note that research on BC-based cloud systems is still developing, with access control being one of the primary challenges faced by researchers. Communication among multiple parties in a rewarded data environment can lead to network disruptions and unexpected financial losses.

The research in the study [25] highlights the decentralized, transparent, and secure nature of BC, positioning it as a next-generation technology for various industrial applications. One such application is the Cloud of Things, which merges CC and IoT. By addressing challenges faced by the Cloud of Things, such as decentralization, data privacy, and network security, BC provides innovative solutions. In turn, the Cloud of Things offers flexibility and scalability to enhance BC's efficiency. This synergy has given rise to a new paradigm known as BCoT (blockchain and Cloud of Things integration), which is viewed as a promising enabler for numerous application scenarios. BCoT effectively harnesses the strengths of both technologies to create a more efficient and secure environment.

In summary, the studies show that the integration of BC, AI, IoT, and CC is driving innovation across multiple sectors, including smart cities, healthcare, energy management, and supply chains. AI plays a critical role in enhancing blockchain's capabilities, addressing its limitations, and enabling smarter IoT solutions. Distributed intelligence and decentralized systems are essential for improving IoT scalability, efficiency, and security. Challenges such as energy consumption, interoperability, data privacy, and regulatory frameworks remain critical areas for future research. The convergence of these technologies is paving the way for sustainable, secure, and efficient systems, aligning with the goals of Society 5.0. These studies collectively highlight the transformative potential of integrating BC, AI, IoT, and CC while emphasizing the need for continued research to address existing challenges and unlock new opportunities.

3. A platform for Scoiety 5.0

Society 5.0 will be founded on four essential technological components: 1) IoT-based Cloud applications, 2) cloud-based IoT applications, 3) artificial intelligence (AI), and 4) blockchain (BC). Together, these components will play a significant role in shaping the future technological landscape, facilitating advancements across various sectors and applications. The conceptual model of this platform is illustrated in **Figure 1**.

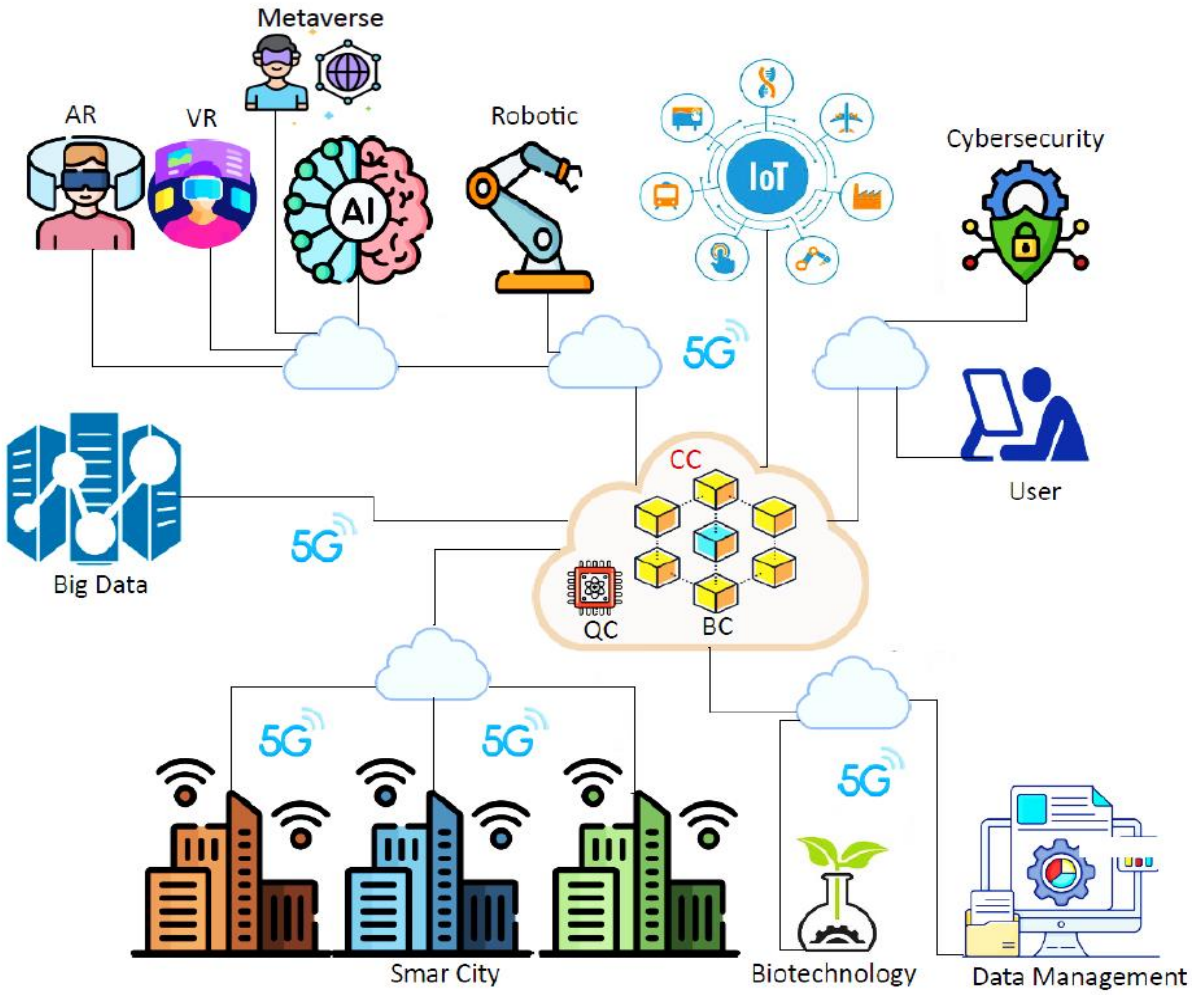

Figure 1. Society 5.0 platform.

3.1. IoT-based cloud applications

Combining IoT systems with cloud-based platforms enhances the ability to store, process, and interpret data collected from connected devices like sensors and actuators. These devices capture information on environmental factors such as temperature, movement, and moisture levels, which is subsequently transmitted to the cloud for in-depth evaluation. The cloud offers a dynamic and adaptable framework capable of managing the massive amounts of data produced by IoT systems, empowering organizations to gain actionable insights into areas like resource usage, supply chain optimization, and consumer trends.

Nevertheless, deploying IoT-driven cloud solutions introduces challenges related

to data protection and privacy, as the data gathered by IoT devices can often include confidential details. Safeguarding this information from breaches and malicious attacks requires the adoption of stringent security measures. These steps are critical to maintaining the privacy, accuracy, and availability of data within such systems.

3.2. Cloud-based IoT applications

IoT applications powered by cloud platforms are specialized software systems that leverage cloud infrastructure to handle and interpret data from connected devices. These systems gather information from sensors, equipment, and other endpoints, process it instantly, and generate actionable insights to improve operational efficiency, boost productivity, and foster innovation.

In contrast to conventional on-site setups, cloud-enabled IoT solutions bring numerous benefits. They support seamless scalability, enabling businesses to expand or reduce their IoT networks as required without major investments in physical infrastructure. Moreover, these solutions are highly adaptable, allowing users to integrate cutting-edge technologies like artificial intelligence (AI) and predictive analytics to uncover trends and enhance decision-making. By combining affordability, efficiency, and versatility, cloud-driven IoT systems present a modern approach to managing and interpreting data from interconnected devices.

It should be noted that the terms "IoT-Based Cloud Applications" and "Cloud-Based IoT Applications" may sound similar, but they emphasize different aspects of the relationship between the Internet of Things (IoT) and cloud computing. Here's a breakdown of their differences:

3.2.1. IoT-based cloud applications

These applications are primarily "cloud-centric", meaning the cloud is the main platform, and IoT devices are used to enhance or enable cloud-based functionalities. The cloud application leverages IoT devices to collect data, perform analytics, or enable automation, but the core functionality resides in the cloud. A cloud-based fleet management system that uses IoT devices (e.g., GPS trackers, sensors) to monitor vehicles and optimize routes. The cloud application processes the data and provides insights, but the IoT devices are secondary to the cloud platform.

3.2.2. Cloud-based IoT applications

These applications are "IoT-centric", meaning the IoT devices are the primary focus, and the cloud is used to support or enhance their functionality. The IoT devices collect and transmit data to the cloud for storage, processing, or further analysis. The cloud acts as a backend service to enable scalability, real-time analytics, or remote control of IoT devices. A smart home system where IoT devices (e.g., thermostats, cameras, lights) send data to the cloud for remote monitoring and control. The cloud is essential for managing the IoT ecosystem, but the IoT devices are the core of the application.

3.3. AI

Artificial intelligence (AI) refers to the creation of computational systems designed to execute functions that traditionally demand human cognitive abilities.

These functions encompass activities like image interpretation, voice detection, decision-making, and language conversion. AI relies on sophisticated algorithms and data-driven models, allowing machines to learn from information and refine their functionality over time. The primary objective of AI is to build systems that can tackle intricate challenges and make decisions with a level of efficiency comparable to or surpassing human capabilities.

AI finds utility in a wide range of sectors, such as healthcare, banking, education, logistics, and media. The field is evolving at a rapid pace, with innovations in areas like neural networks, language understanding, and visual recognition pushing the boundaries of what AI can achieve.

Despite its potential, the rise of AI brings forth significant ethical and societal questions. Concerns include its influence on employment, the protection of personal information, and the possibility of biased outcomes. As AI technologies grow more advanced, there is apprehension about their impact on job markets, potentially leading to workforce disruptions and the need for reskilling. Additionally, the collection and analysis of large datasets by AI systems raise critical issues around data security and individual privacy. Lastly, the risk of AI systems perpetuating or amplifying biases (whether from skewed training data or flawed algorithms) poses serious challenges for fairness and equality in society.

3.4. BC

A system that combines blockchain (BC), artificial intelligence (AI), and the Internet of Things (IoT) can establish a highly sophisticated and interconnected ecosystem, revolutionizing multiple sectors by boosting efficiency, security, and transparency. Each technology brings distinct strengths to the table. AI can process and interpret the massive datasets produced by IoT devices and cloud-based platforms, enabling smarter decision-making, streamlined processes, and enriched user experiences.

Blockchain technology provides a secure and transparent framework for transactions and data exchanges between IoT devices and cloud systems. It offers functionalities such as tamper-proof digital identity verification, automated smart contracts, and distributed data storage. IoT devices generate continuous streams of real-time data, which AI can analyze, and blockchain can securely store to ensure transparency and accessibility. Cloud platforms act as centralized hubs for data processing, analysis, and storage, supporting advanced applications like predictive analytics, machine learning, and business insights.

The synergy of these technologies can drive significant improvements in efficiency, security, and transparency across diverse fields, including logistics, healthcare, financial services, and urban development. It also promotes collaboration among entities and encourages innovation by enabling seamless data sharing and analysis. A key advantage of this integration is the development of highly secure, decentralized cloud applications. Blockchain’s unalterable ledger and smart contract functionality can create robust systems for data storage and transactions, enhancing privacy and security. Meanwhile, AI and IoT can automate processes and optimize resource allocation, as demonstrated in smart city initiatives like adaptive traffic

control or precision agriculture systems.

Despite these benefits, challenges remain, such as ensuring compatibility between diverse devices and platforms, addressing privacy and data protection concerns, and managing scalability issues due to the enormous volume of IoT-generated data. To fully realize the potential of this integrated approach, strategic planning, cross-sector collaboration, and investments in infrastructure and standardization are crucial. This includes tackling privacy issues, ensuring seamless interoperability, and creating scalable solutions to handle the ever-growing data streams from IoT devices.

Integrating artificial intelligence (AI), blockchain (BC), cloud computing (CC), and the Internet of Things (IoT) into a single platform creates a powerful ecosystem where each technology complements and enhances the capabilities of the others. This integration enables the platform to address complex challenges in Society 5.0, such as automation, security, scalability, and sustainability. Below is a detailed explanation of how these technologies can be integrated and how they interact with each other:

3.5. Role of each technology in the platform

Artificial intelligence (AI):

AI acts as the brain of the platform, enabling intelligent decision-making, predictive analytics, and automation. AI processes vast amounts of data generated by IoT devices to extract meaningful insights. AI automates repetitive tasks, such as monitoring IoT sensors or executing smart contracts on the blockchain. AI predicts trends, anomalies, and potential failures, enabling proactive solutions. AI can analyze traffic data from IoT sensors to optimize traffic flow and reduce congestion.

Blockchain (BC):

Blockchain serves as the trust layer of the platform, ensuring secure, transparent, and tamper-proof transactions and data sharing. BC ensures that data from IoT devices is immutable and verifiable. BC eliminates the need for a central authority, enabling peer-to-peer interactions. BC automates agreements and processes through self-executing smart contracts.

Cloud computing (CC):

Cloud computing acts as the backbone of the platform, providing scalable storage, processing power, and accessibility. CC stores massive amounts of data generated by IoT devices and processed by AI. CC allows the platform to scale seamlessly as the number of IoT devices and users grows. CC enables real-time access to data and services from anywhere in the world.

Internet of Things (IoT):

IoT serves as the sensory layer of the platform, collecting real-time data from the physical world. IoT devices (sensors, cameras, wearables) gather data from the environment. IoT connects physical devices to the digital platform, enabling real-time monitoring and control. IoT devices can execute actions based on commands from AI or smart contracts. In agriculture, IoT sensors monitor soil moisture and send data to the cloud for AI analysis, which then triggers irrigation systems.

3.6. How these technologies interact and enhance each other

AI and IoT: IoT devices generate massive amounts of data, which AI processes to derive insights and make decisions. AI enhances IoT by providing intelligent analytics and automation. IoT enhances AI by providing real-time data for training and decision-making.

AI and blockchain: AI can analyze data stored on the blockchain, while blockchain ensures the integrity and security of AI models and data. AI enhances blockchain by optimizing consensus algorithms and detecting fraudulent transactions. Blockchain enhances AI by providing a secure and transparent data source for training and validation. In finance, AI can detect fraudulent transactions on a blockchain-based payment system.

AI and cloud computing: AI relies on cloud computing for data storage and computational power, while cloud platforms use AI to optimize resource allocation. AI enhances cloud computing by enabling predictive maintenance and resource optimization. Cloud computing enhances AI by providing scalable infrastructure for training and deploying AI models.

Blockchain and IoT: Blockchain ensures the security and integrity of data generated by IoT devices, while IoT provides real-world data for blockchain applications. Blockchain enhances IoT by providing a decentralized and secure framework for data sharing. IoT enhances blockchain by providing real-time data for smart contracts and transactions.

Blockchain and cloud computing: Blockchain can be hosted on cloud platforms, while cloud computing benefits from blockchain's security and decentralization. Blockchain enhances cloud computing by providing secure and transparent data storage. Cloud computing enhances blockchain by providing scalable infrastructure for blockchain networks.

IoT and cloud computing: IoT devices send data to the cloud for storage and processing, while cloud platforms provide the infrastructure for IoT applications. IoT enhances cloud computing by providing real-time data for cloud-based services. Cloud computing enhances IoT by providing scalable storage and processing power.

4. Issues, challenges, and opportunities

The terms challenges and issues are often used interchangeably, but they have nuanced differences, especially in the context of integrating AI, blockchain, IoT, and cloud computing in smart cities. Challenges refer to difficulties or obstacles that need to be overcome to achieve a goal. They often require strategic planning, innovation, and collaboration to address. Challenges are often proactive; they are anticipated problems that can be planned for and mitigated. Challenges are more about how to achieve something despite the difficulties.

Issues refer to existing problems or concerns that are already present and need to be resolved. They are often more immediate and tangible. Issues are often reactive; they are problems that have already arisen and need to be fixed. Issues are more about what is currently wrong and how to fix it.

Challenges are the potential obstacles that cities, governments, and organizations might face when trying to implement and integrate these technologies. These

challenges are often forward-looking and require innovative solutions. Issues are the existing problems that have already emerged due to the integration of these technologies. These issues are often immediate and require urgent attention.

1) Issues

Integrating blockchain (BC), artificial intelligence (AI), Internet of Things (IoT), and cloud applications presents several open issues that need to be addressed for seamless and efficient operation. Some of these challenges include:

- Interoperability: The ability of different devices or systems to work together seamlessly, known as interoperability, poses a significant challenge in IoT and cloud platforms. The lack of standardization and compatibility among various IoT devices and cloud platforms, as noted in reference [26], complicates this issue. BC technology has the potential to create a more standardized ecosystem, but it is essential to further advance and refine these technologies to fully tackle interoperability challenges in the IoT and cloud environments.
- Security and Privacy: As the number of IoT devices connected to cloud platforms increases, so do concerns about security and privacy. The sensitive nature of the data exchanged and stored in these systems makes these issues increasingly critical. Although BC technology enhances security through its distributed and decentralized nature, it is vital to develop and strengthen additional security measures, such as encryption and access control, as highlighted in reference [27]. This will help protect data and maintain trust within the IoT and Cloud ecosystems.
- Data Management: Managing and interpreting the vast amounts of data generated by IoT devices presents another significant challenge. While AI can play a crucial role in processing and analyzing this data, it is important to create more efficient and scalable data storage and retrieval mechanisms. Reference [28] proposes that developing these mechanisms is essential for effectively managing and deriving insights from the data produced in the IoT ecosystem.
- Scalability: Scalability is a major concern in IoT systems that incorporate blockchain, as the network's efficiency tends to decrease, and congestion increases with the addition of more IoT devices. Researchers are actively investigating potential solutions, such as sharding and side chains, as discussed in reference [29]. These strategies aim to enhance the overall scalability and efficiency of IoT systems utilizing blockchain technology, ensuring their continued growth and effectiveness.
- Energy Efficiency: Energy efficiency is crucial in IoT systems that integrate blockchain, given the substantial energy consumption of connected devices. Ongoing research focuses on developing more energy-efficient IoT devices and blockchain consensus algorithms, as emphasized in reference [30]. Improvements in energy efficiency will contribute to the sustainability and long-term viability of IoT systems relying on blockchain technology.

2) Challenges

Finally, the integration of blockchain (BC), artificial intelligence (AI), Internet of Things (IoT), and Cloud technologies presents new governance and regulatory challenges. To ensure these technologies are used responsibly and in compliance with

privacy and security laws, it is essential to establish clear guidelines and regulations, as suggested in reference [23]. These measures will facilitate the safe and efficient implementation of these advanced technologies, fostering a secure digital environment for all users.

(1) Legal Challenges

The integration of artificial intelligence (AI), blockchain (BC), the Internet of Things (IoT), and cloud-based systems introduces a range of legal challenges that must be addressed to ensure responsible and lawful use. Key issues include data privacy, intellectual property rights, liability and accountability, interoperability, and the need for adaptable regulatory frameworks. Tackling these challenges is essential for creating a secure, efficient, and trustworthy digital ecosystem that encourages innovation. Below are some of the most pressing legal concerns:

- Data Protection and Privacy: Safeguarding data privacy is a critical legal issue in the context of AI, BC, IoT, and cloud applications. The massive volumes of data generated by IoT devices require stringent security measures to comply with privacy regulations like the General Data Protection Regulation (GDPR). Such laws provide a robust framework for protecting individual privacy rights, particularly in regions like the European Union and the European Economic Area. Adhering to these regulations is vital for maintaining user trust and ensuring that personal data is handled responsibly.
- Intellectual Property Rights: The rapid advancement of AI algorithms and IoT devices has heightened concerns around intellectual property (IP) protection. Securing IP rights is crucial for fostering a fair and competitive innovation landscape. Blockchain technology can play a pivotal role here by offering a decentralized and secure platform for managing IP rights. It enables creators to track, verify, and protect their innovations effectively. However, further research is needed to fully integrate blockchain with existing IP systems, enhancing transparency and efficiency in IP management.
- Liability and Accountability: As autonomous systems powered by AI, BC, IoT, and cloud technologies become more prevalent, determining responsibility and accountability for damages or malfunctions poses a significant legal challenge. Clear legal frameworks are needed to define liability and ensure accountability. Without such guidelines, resolving disputes or addressing issues arising from these technologies becomes complicated. Establishing comprehensive legal structures will not only facilitate dispute resolution but also encourage innovation by clarifying stakeholder responsibilities.
- Interoperability and Standardization: The convergence of AI, BC, IoT, and cloud technologies introduces governance and regulatory complexities. Developing clear guidelines and standards is essential to ensure ethical use and compliance with privacy and security laws. Standardization is particularly important for enabling seamless communication and data sharing across diverse IoT devices and cloud platforms. A standardized ecosystem will promote interoperability, fostering a more integrated and efficient technological environment.
- Cybersecurity and Cybercrime: While AI, BC, IoT, and cloud applications offer significant benefits, they also present cybersecurity risks. Although blockchain

provides a secure infrastructure, it is not entirely immune to vulnerabilities. Legal frameworks focused on cybersecurity and cybercrime must be developed to address these risks. These frameworks should encompass prevention, detection, response, and recovery strategies. Collaboration among governments, industry stakeholders, and cybersecurity experts will be crucial in creating effective legal measures to combat cyber threats and ensure the sustainable adoption of these technologies.

By addressing these legal challenges, stakeholders can create a secure, transparent, and ethical environment for the integration and advancement of AI, blockchain, IoT, and cloud technologies. This will not only promote innovation but also build public trust in these transformative systems.

(2) Study challenges:

The intersection of blockchain, artificial intelligence, the Internet of Things, and cloud-based systems opens up a wealth of research possibilities. This multidisciplinary field presents several pressing challenges that warrant academic exploration, including:

- Integration Complexity: A primary research challenge lies in harmonizing AI algorithms with IoT systems while embedding blockchain technology. While AI is adept at analyzing the extensive data produced by IoT devices, merging these advanced technologies is intricate and demands significant research and development to achieve seamless functionality.
- Blockchain Consensus Mechanisms: Designing efficient and scalable consensus protocols tailored for blockchain-enabled IoT networks is a crucial research focus. Existing mechanisms like Proof-of-Work (PoW) and Proof-of-Stake (PoS) often fall short for IoT applications due to their energy-intensive nature and scalability constraints. Developing innovative alternatives is essential to address these limitations.
- Security and Privacy Enhancements: Strengthening security and privacy in AI, blockchain, IoT, and cloud ecosystems is a critical research priority. Although blockchain offers a decentralized and secure framework, continuous advancements are necessary to adapt to the evolving demands of these interconnected systems. Research efforts must focus on safeguarding sensitive data and ensuring robust protection against emerging threats.
- Data Management and Analytics: Managing and analyzing the massive, diverse, and fast-paced data streams generated by IoT devices requires scalable and efficient solutions. Researchers must devise novel approaches to process and interpret this data, unlocking its potential to drive insights and optimize operations.
- Interoperability Standards: Establishing uniformity and interoperability across diverse IoT devices and cloud platforms is a significant research challenge. While blockchain can contribute to a more standardized environment, further investigation is needed to define protocols that enable seamless communication and data exchange between different systems, fostering a cohesive IoT ecosystem.
- Energy Efficiency Optimization: Enhancing energy efficiency in IoT systems

utilizing blockchain is a vital area of study. Developing energy-conscious IoT devices and consensus algorithms specifically for blockchain applications is crucial for system stability and sustainability. Reducing energy consumption will improve performance and minimize the environmental footprint of IoT networks.

- Governance and Regulatory Frameworks: The integration of IoT and blockchain introduces new governance and regulatory complexities. Researchers must explore the societal implications of these technologies and formulate comprehensive guidelines to ensure their ethical and responsible adoption. This will help maintain public trust and facilitate their smooth integration into everyday life.

By addressing these challenges, researchers can unlock the full potential of integrating blockchain, AI, IoT, and cloud technologies, paving the way for innovative solutions across industries.

3) Opportunities

The convergence of blockchain (BC), artificial intelligence (AI), and the Internet of Things (IoT) holds immense potential to revolutionize the development of intelligent, decentralized, and secure cloud-based solutions. This powerful combination can drive innovation and growth across multiple industries, offering a wealth of future research opportunities centered on IoT-enabled cloud applications. By harnessing the unique capabilities of these technologies, researchers can create cutting-edge, secure, and efficient systems tailored to diverse sectors. Key areas of exploration include:

- Smart Cities: Researchers can investigate the application of AI-powered predictive analytics and blockchain-enabled secure data sharing to enhance urban infrastructure, traffic control, public safety, and environmental sustainability. This integrated approach can improve living standards, support eco-friendly initiatives, and drive economic development by addressing modern urban challenges while ensuring data integrity and transparency.
- Energy Management: The fusion of AI, blockchain, and IoT can pave the way for intelligent energy systems. By employing AI-based predictive tools and blockchain-driven smart contracts, researchers can optimize energy distribution, enable peer-to-peer energy exchanges, and promote the use of renewable energy. This approach can foster sustainable energy practices and bolster energy reliability.
- Supply Chain Optimization: The integration of AI, blockchain, and IoT can revolutionize supply chain operations by enhancing transparency and efficiency. Researchers can utilize machine learning and smart contracts to streamline processes, automate transactions, and improve risk management. This synergy can reduce operational costs, enhance collaboration among stakeholders, and build a more sustainable and resilient supply chain network.
- Healthcare Transformation: The combination of AI, blockchain, and IoT can redefine healthcare delivery by enabling real-time patient monitoring, tailored treatments, and secure data exchange. Researchers can leverage AI-driven diagnostics and blockchain's secure data-sharing features to improve treatment accuracy, operational efficiency, and preventive care. This approach can lead to

better health outcomes, increased patient trust, and a more streamlined healthcare system.

- Agricultural Innovation: Integrating AI, blockchain, and IoT into agriculture can modernize farming practices by enabling real-time tracking of crops, soil conditions, and weather patterns. This supports precision agriculture, optimizing resource use and boosting productivity. Researchers can use AI-based analytics and blockchain's secure data-sharing mechanisms to lower costs, enhance sustainability, and improve overall agricultural performance. By encouraging collaboration and innovation, this integration can contribute to a more resilient and eco-conscious agricultural industry.

These research opportunities highlight the transformative potential of combining AI, blockchain, and IoT, offering solutions that are not only technologically advanced but also secure, efficient, and sustainable. By addressing these areas, researchers can drive meaningful progress across industries and contribute to a smarter, more connected future.

5. Conclusion

The integration of blockchain (BC), artificial intelligence (AI), and the Internet of Things (IoT) represents a transformative leap toward realizing the vision of Society 5.0. These technologies, when combined, enable the development of smart, secure, and decentralized cloud applications that are capable of automating decision-making processes, optimizing resource utilization, and enhancing data privacy and security. This paper has explored the convergence of these technologies, highlighting their potential to address critical challenges and unlock new opportunities across various sectors.

5.1. Theoretical implications

From a theoretical perspective, this research contributes to the growing body of knowledge on the integration of BC, AI, and IoT by: 1) Advancing Interdisciplinary Understanding: The study bridges the gap between these technologies, offering a holistic framework for their integration in the context of Society 5.0. 2) Identifying Key Challenges: The paper systematically outlines critical challenges such as interoperability, data privacy, security, and scalability, providing a foundation for future research. 3) Proposing a Unified Framework: By emphasizing the need for collaboration among stakeholders, the study proposes a collaborative approach to developing infrastructure and standards, which can serve as a blueprint for future implementations.

5.2. Practical implications

From a practical standpoint, the findings of this research have significant implications for industries, governments, and academia: 1) Industry Applications: Organizations can leverage the integration of BC, AI, and IoT to create intelligent systems that enhance efficiency, reduce costs, and improve customer experiences. For example, in healthcare, this integration can enable secure and real-time patient monitoring, while in supply chain management, it can ensure transparency and

traceability. 2) Policy Development: Governments and regulatory bodies can use the insights from this study to develop policies and standards that promote interoperability, data privacy, and security in smart cities and other IoT-driven ecosystems. 3) Innovation and Investment: The research underscores the importance of investing in research and development to address scalability and performance challenges, encouraging stakeholders to allocate resources toward innovative solutions.

5.3. Addressing challenges

To fully realize the potential of this convergence, it is crucial to address several challenges: 1) Interoperability: Ensuring seamless communication and data sharing between diverse devices and systems remains a critical hurdle. 2) Data Privacy: Organizations must adopt robust mechanisms to protect sensitive information while leveraging these technologies. 3) Security: Safeguarding systems and data from cyber threats is essential for building trust and ensuring widespread adoption. 4) Scalability: Solutions must be designed to handle the exponential growth of data generated by IoT devices without compromising performance.

5.4. Collaboration and future directions

Collaboration among industry, academic institutions, and government bodies is essential for developing the infrastructure and standards needed to support this technological integration. By working together, these stakeholders can establish a solid foundation for the adoption and implementation of AI, BC, and IoT technologies. Future research should focus on: 1) developing energy-efficient blockchain protocols, 2) enhancing AI algorithms to reduce bias and improve decision-making, and 3) creating scalable IoT architectures that can handle the demands of smart cities.

The opportunities presented by a BC-based IoT Cloud environment are immense and have the potential to revolutionize various sectors, including healthcare, transportation, energy, and manufacturing. By embracing this convergence and investing in research and innovation, organizations can contribute to a more efficient, sustainable, and secure future. This not only drives economic growth and innovation but also enhances the quality of life for individuals across different sectors and industries. The integration of BC, AI, and IoT is not just a technological advancement; it is a step toward building a smarter, more connected, and human-centric society.

Author contributions: Conceptualization, YG and MRG; methodology, MRG; software, MRG; validation, YG and MRG; formal analysis, MRG and YG; investigation, YG and MRG; resources, YG and MRG; data curation, MRG; writing—original draft preparation, MRG; writing—review and editing, YG; visualization, YG; supervision, MRG; project administration, MRG; funding acquisition, YG. All authors have read and agreed to the published version of the manuscript.

Conflict of interest: The authors declare no conflict of interest.

References

1. Bublitz FM, Oetomo A, Sahu KS, et al. Disruptive Technologies for Environment and Health Research: An Overview of

Artificial Intelligence, Blockchain, and Internet of Things. International Journal of Environmental Research and Public Health. 2019; 16(20): 3847. doi: 10.3390/ijerph16203847
2. Sá MJ, Santos AI, Serpa S, Ferreira CM. Digital literacy in digital Society 5.0. Academy Journal of Interdisciplinary Studies. 2021; 10(2): 1–9.
3. Al Mubarak M. Sustainably developing in a digital world: Harnessing artificial intelligence to meet the imperatives of work-based learning in Industry 5.0. Development and Learning in Organizations. 2023; 37(3): 18-20.
4. Zizic MC, Mladineo M, Gjeldum N, et al. From Industry 4.0 towards Industry 5.0: A Review and Analysis of Paradigm Shift for the People, Organization and Technology. Energies. 2022; 15(14): 5221. doi: 10.3390/en15145221
5. Shahrubudin N, Te Chuan L, Ramlan RJPM. An overview on 3D printing technology: Technological, materials, and applications. Procedia Manufacturing. 2019; 35: 1286–1296.
6. Dhar P, Rocks T, Samarasinghe RM, et al. Augmented reality in medical education: students' experiences and learning outcomes. Medical Education Online. 2021; 26(1). doi: 10.1080/10872981.2021.1953953
7. Gupta A, Rayeen F, Mishra R, et al. Nanotechnology applications in sustainable agriculture: An emerging eco-friendly approach. Plant Nano Biology. 2023; 4: 100033. doi: 10.1016/j.plana.2023.100033
8. Rabbi MF, Popp J, Máté D, et al. Energy Security and Energy Transition to Achieve Carbon Neutrality. Energies. 2022; 15(21): 8126. doi: 10.3390/en15218126
9. Idrees SM, Nowostawski M, Jameel R, et al. Security Aspects of Blockchain Technology Intended for Industrial Applications. Electronics. 2021; 10(8): 951. doi: 10.3390/electronics10080951
10. Sandner P, Gross J, Richter R. Convergence of blockchain, IoT, and AI. Blockchain Science. 2020; 3. doi: 10.3389/fbloc.2020.522600
11. Lnenicka M, Kysela T, Horák O. Building security and resilience: a guide to implementing effective cybersecurity and data protection measures in smart cities. Smart and Sustainable Built Environment; 2025.
12. Adhikari M, Ghimire LP, Kim Y, et al. Identification and Analysis of Barriers against Electric Vehicle Use. Sustainability. 2020; 12(12): 4850. doi: 10.3390/su12124850
13. Gill SS, Kumar A, Singh H, et al. Quantum computing: A taxonomy, systematic review and future directions. Software: Practice and Experience. 2022; 52(1): 66–114.
14. Katz L, Chen YY, Gonzalez R, et al. Synthetic biology advances and applications in the biotechnology industry: A perspective. Journal of Industrial Microbiology & Biotechnology. 2018; 45(7): 449-461.
15. Mishra S, Tyagi AK. Emerging trends and techniques in machine learning and Internet of Things-based cloud applications. In: Handbook of Research on Internet of Things and Cyber-Physical Systems. Apple Academic Press; 2022.
16. Allam Z, Dhunny ZA. On big data, artificial intelligence and smart cities. Cities. 2019; 89: 80-91. doi: 10.1016/j.cities.2019.01.032
17. Aramesh S, Chan M, Yang W, et al. A Systematic Review of Internet of Things (Iot) Adoption Through Technology Adoption Theories: Insights, Challenges and Future Directions. SSRN; 2025.
18. Onwuegbuzie IU, Ajibade SM. 5G: Next generation mobile wireless technology for a fast-pacing world. Journal of Pure and Applied Science (JPAS). 2022; 1(1): 1-9.
19. Javaid M, Haleem A, Singh PR, Suman R. Substantial capabilities of robotics in enhancing Industry 4.0 implementation. Cognitive Robotics. 2021; 1: 58-75.
20. Nair MM, Tyagi AK. AI, IoT, blockchain, and cloud computing: The necessity of the future. In: Pandey R, Goundar S, Fatima S (editors). Distributed Computing to Blockchain. Academic Press; 2023.
21. Ahmed I, Zhang Y, Jeon G, et al. A blockchain- and artificial intelligence-enabled smart IoT framework for sustainable city. International Journal of Intelligent Systems; 2022.
22. Gill SS, Tuli S, Xu M, et al. Transformative effects of IoT, Blockchain and Artificial Intelligence on cloud computing: Evolution, vision, trends and open challenges. Internet of Things. 2019; 8: 100118. doi: 10.1016/j.iot.2019.100118
23. Singh SK, Rathore S, Park JH. (2020) Block IoT intelligence: A blockchain-enabled intelligent IoT architecture with artificial intelligence. Future Generation Computer Systems. 2020; 110: 721–743.
24. Rababah B, Alam T, Eskicioglu R. The next generation Internet of Things architecture towards distributed intelligence: Reviews, applications, and research challenges. SSRN; 2020.
25. Sarmah SS. Application of blockchain in cloud computing. International Journal of Innovative Technology and Exploring Engineering. 2019; 8(12).

26. Nguyen DC, Pathirana PN, Ding M, Seneviratne A. Integration of blockchain and cloud of things: Architecture, applications, and challenges. IEEE Communications Surveys & Tutorials. 2020; 22(4): 2521-2549.
27. Do J, Ferreira VC, Bobarshad H, et al. Cost-effective, energy-efficient, and scalable storage computing for large-scale AI applications. ACM Transactions on Storage. 2020; 16(4): 1-37.
28. Bouzerzour NEH, Ghazouani S, Slimani Y. A survey on the service interoperability in cloud computing: Client-centric and provider-centric perspectives. Software: Practice and Experience. 2020; 50(7): 1025-1060. doi: 10.1002/spe.2794
29. Xu X, Zhao H, Yao H, Wang S. A blockchain-enabled energy-efficient data collection system for UAV-assisted IoT. IEEE Internet of Things Journal. 2020; 8(4): 2431-2443.
30. Tang Y, Xiong J, Becerril-Arreola R, Iyer L. Ethics of blockchain: A framework of technology, applications, impacts, and research directions. Information Technology & People. 2020; 33(2): 602-632.