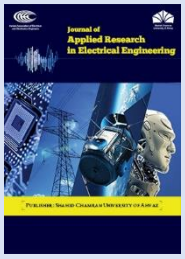
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Review Article

A Review on Blockchain-based Gaming: Existing Insights, Deficits, and Emerging Avenues

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Abstract: Gaming is the notion of playing electronic games that involves users in the form of avatars or characters engaging with an interactive digital experience to achieve a specific gaming objective. Blockchains can enhance the overall gaming platform by helping to provide auditing, transparency, incentivization, security, and verification features in gaming. We analyze distinct blockchain-stemmed gaming structures, understand 11 tasks of blockchain-stemmed gaming reflection, and investigate them extensively regarding gaming- and blockchain-linked qualities. We packed an inaugural sample of 94 paper origins by extracting the papers for filtering standards chased down from E-collections, imposing a systematic and longish quality assessment scheme. Derived from the study, in blockchain-stemmed gaming, blockchain can support game auditing (C1), game incentivization (C2), gamification (C3), cooperative game play (C4), game fraud prevention and fair play (C5), game DApps with extendibility (C6), game asset ownership protection and asset transactions (C7), game user-produced elements security (C8), game credential verification (C9), game rule transparency (C10), and crypto gaming (C11). Extensive investigation discovers that in blockchain-stemmed gaming, 21.7% exploit gamification (C3), 75.6% exploit linear blockchain, and 10.8% exploit PoS consensus. As deficits, consensus approaches like proof of authority and stake, and unconventional blockchain are rarely used, while blockchain-based gaming concepts such as C1, C8, and C10 are deficient. Ultimately, we expose the advantages and asperities of the reflection of blockchain-stemmed gaming and then extend offers to shrink them.

Keywords: Gaming, Blockchain, Copyright, Fraud prevention, Auditing.

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1. INTRODUCTION

In gaming, rules define how players deal with the game, and among them are two types of rules: formal rules that are formally defined and written for gaming and the other is informal, unwritten rules that are not formally expressed but need to be learned by the player to play the game [1]. In traditional games, game assets are owned by the game operator, while in blockchain-based gaming, assets can be owned by the players [2]. In contrast to traditional games, in which all assets are created by the game creators, user-produced elements are a new and emerging concept that allows players to produce and share their customized creations within the game environment [3]. In multi-modal multiplayer gaming environments, speech input and multimodal gestures facilitate the user to interact collaboratively within the game [4]. In character customization, players can create unique avatars by selecting different appearance options, while in a war game, weapons and equipment can be customized [5]. Game accessibility options include adjustable difficulty levels, scalable text sizes, and colorblind modes, allowing the game to be able to be played by a differently abled audience [6].

The game contains the software, content, mechanics, and design elements that define the player experience, and it can provide excitement, fear, happiness, security, insecurity, or indifference as an objective feeling to the end-users [7]. The game client communicates with the game server to exchange data like player actions, game state updates, player information, etc., while the game server is responsible for managing the game world, processing game logic, and communicating between multiple clients [8]. Authentication is critical in online games to identify the users they claim to be and provide permissions to use the game's features. In

order to achieve this process, users need to log in, and once logged in, they are provided with an authentication token [9]. Analytics can provide an insight into the player's behavior such that the game can be updated dynamically to suit the player's behavior. Research in [10] has shown that, using a multi-level game theoretical model, subordinates and principals at organizational levels should have explicit contracts for monitoring and sanctioning, where agents are players.

By simulating real-world scenarios, serious games aim to bring behavioral changes in the participants of the game subsequent to playing the game and can simulate real-world situations that may be difficult to implement in reality due to safety concerns, cost, time consumption, etc. while aiming to develop the gamer's skill [11]. On the other hand, gamification integrates game-like features such as points, badges, leaderboards, and challenges into non-game-related activities in order to motivate the desired activity [12]. Within game user research, it involves studying the interaction among players and their surroundings, using the interaction between humans and computers, studying media, and studying social science in diverse game types, not limited to entertainment games [13]. In a study that assessed the backend side of massive multiplayer online gaming, it was shown that the infrastructure-as-a-service tier performs superiorly to the platform-as-a-service tier in cloud platforms in terms of real-time latency [14]. This work surveys diverse approaches where blockchain has been utilized in numerous gaming concepts discussed above.

Blockchain is a decentralized ledger scheme that securely records transactions across a network of computers [15]. In a linear blockchain, there is a successive block continuum leveraging cryptographic hash links [16]. A non-conventional blockchain deviates from the linear blockchain, where transactions are not grouped into blocks, but individually linked to multiple previous transactions [17]. A digital signature, which is realized using public-key cryptography, is used to warrant the authenticity of transactions by using a private key for signing them and a public key to verify the signatures [18]. Smart contracts autonomously apply agreements banning the requisite for middlemen, reducing the risks of fraud and falsification, and are further strengthened by a high degree of trust thanks to blockchain's immutable features [19].

Centered around this investigation, the blockchain-stemmed gaming reflection can be ranked among the 11 tasks. First, within game auditing, the data stored in the blockchain can be utilized for auditing the game [20]. Next, within game incentivization, it includes the principle of the play-to-earn concept, or it involves trading in-game virtual assets with the aid of blockchains and tokens/cryptocurrencies [21]. Alternatively, in blockchain-driven gamification, a gamified concept is utilized along with blockchain-driven storage and collaboration to improve security and trust [22]. Further, blockchains can provide cooperative game play by facilitating the creation of cooperative game worlds, using specific cooperative consensus approaches that are based on cooperative game play, or maintaining cooperative scoring systems [23]. Next, in blockchain-stemmed game fraud prevention and fair play, game fraud like cheating is avoided using smart contracts and consensus mechanisms and also includes fair maintenance of true randomness without skewness from third parties [24]. Moreover, game DApps can be administered to perform a certain operation related to the game, such as opening a loot box with high trustworthiness [25]. Then, in blockchain-stemmed game asset ownership protection and asset transactions, game assets are typically tokenized and associated with the digital IDs of the players, and ownership regarding assets is stored on the blockchain [26]. Next, blockchains can provide transparency and accountability for game user-produced elements' security and also be utilized for game credential verification by implementing authentication and access control with the assistance of smart contracts [27]. In blockchain-stemmed game rule transparency, game rights and rules are implemented as a distributed system with the approval of peers [28]. Finally, crypto gaming refers to storing in-game resources that exist as tokens in the blockchain on top of a cryptocurrency network and trading game assets for cryptocurrency [29].

We found two review papers that have been published so far related to blockchain-based gaming. In the first paper, the authors do a systematic exploration of how blockchain has been utilized to improve educational gaming and provide insights for educational institutes [30]. In the second one, the reviewers discuss the crypto games using Ethereum as the cryptocurrency while comparing game characteristics with legal gambling perspectives [31]. However, to our perception, so far no one has done a survey on the whole blockchain-based gaming concept, discussing diverse aspects of game auditing, fraud prevention, asset ownership protection, incentivization, credential verification, rule transparency, etc. using blockchain technology. Thus, we aim to fulfill that deficiency by using this appraisal.

Fig. 1 disseminates the title listing of this inspection.

1.1. Contribution to Conventional Literature

- We separated and briefly illustrated the gaming idea (Section 3);
- An outline of the blockchain structure is exposed (Section 4);
- Analyze conventional blockchain-stemmed gaming structures (Section 5);
- Investigate extensively on the analyzed blockchain-stemmed gaming structures (Section 6);
- The advantages and asperities of blockchain-stemmed gaming are exposed (Section 7);
- Offers and coming ways for harnessing blockchain-stemmed gaming are exposed (Section 8).

2. METHODOLOGY

This study analyzes the active examinations of blockchain-stemmed gaming spread as digital files throughout history, imposing a systematic and longish mixed-method quality evaluation scheme [32].

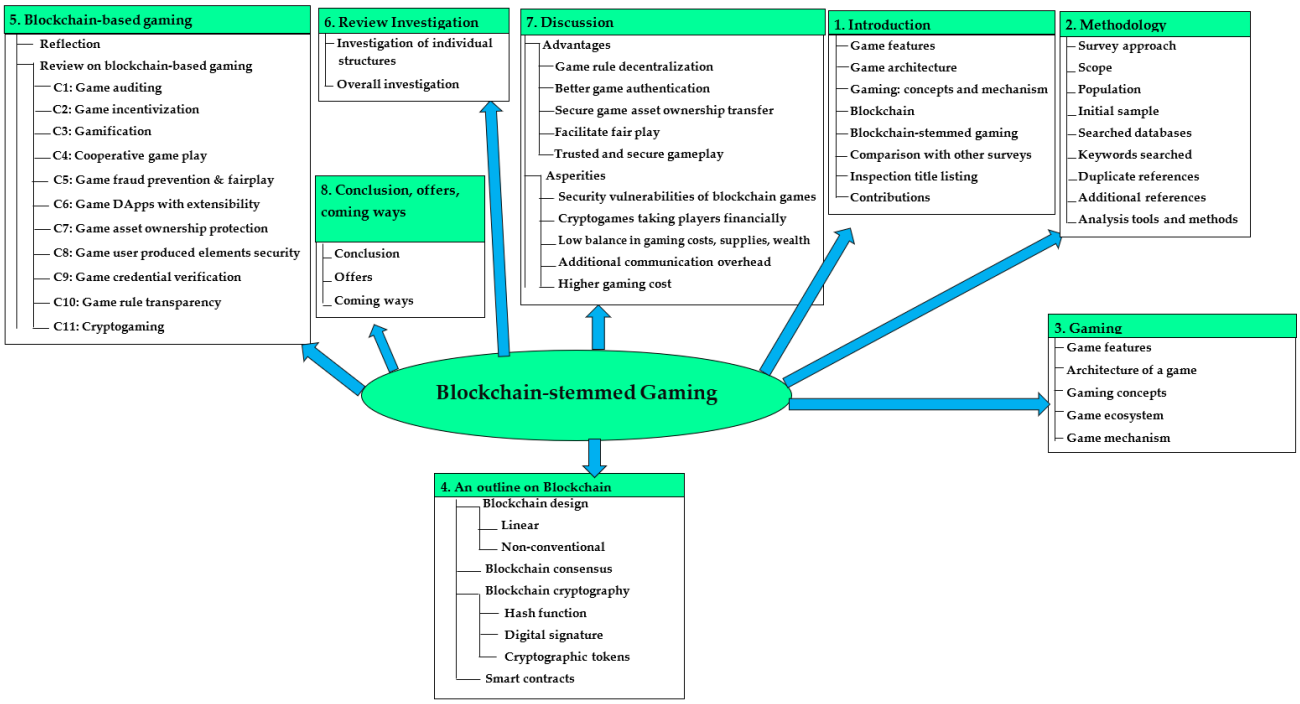


Fig. 1: Title listing of blockchain-stemmed gaming inspection.

Particularly, it evaluates a combination of the principles of gaming and blockchain. Therefore, all unprecedented research papers and cyberworld papers posted on gaming, blockchain-stemmed gaming, and blockchain characterize the scenario set in the setting of this study. However, the scenario-set sources are enigmatic to explore. Hence, imposing the pertinent investigating terms and filtering standards, we packed 97 sources from unprecedented research papers and cyberworld papers.

We chased down Google Scholar, ScienceDirect, ACM Digital Library, Wiley Online Library, MDPI, and IEEE Xplore Digital Library. The favorite investigating terms were "Gaming" OR "Blockchain-stemmed gaming" OR "Blockchain-stemmed user produced content" OR "Blockchain-maintained game rules transparency" OR "Blockchain-maintained virtual assets" OR "Blockchain-stemmed multiplayer functionality" OR "blockchain and game architectures" OR "blockchain-stemmed game monitoring and analytics" OR "Blockchain-stemmed serious games" OR "Blockchain-stemmed gamification" OR "Blockchain-stemmed game authentication" OR "Blockchain-stemmed game auditing" OR "Blockchain-stemmed game fraud prevention" OR "Blockchain and game incentivization" OR "Blockchain and game asset ownership protection" OR "blockchain and game asset reusability" OR "Blockchain".

Some factors in extracting the papers articulated the filtering standards. First, the referenced research orders English phrasing, and thereafter, it orders exceptional connection to the investigating term. Next, for elevating the reliableness of the conducted study, serial articles were supplied with a raised preference than seminar papers and non-peer-reviewed content. We didn't prioritize unprecedented research papers within a specified content producer satisfying the filtering standards; rather, we processed all content producers equivalently. The final filtering standard publishes that a specified unprecedented conceptual essay orders revelation within the time of 1975 and 2024.

The inaugural sample was moderated to 94 origins of papers; latterly, it was disclosed that 3 origins were surpluses. We quoted conceptions and illustrations employing 38 paper origins. To complement this study with prevalent studies, we at last fused 2 literature analysis papers to the assemblage of papers, shifting the universal volume of origins of papers to 134.

To study accumulated blockchain-stemmed gaming, we drew on the catalogs for study categorization. We drafted realizations drawing on Office 365 to objectively oversee study data glued to gaming- and blockchain-stemmed factors [33].

3. GAMING

3.1. Game Features

3.1.1. Rules

Rules are considered the building blocks of a game since they define how participants deal with the game and among them. There exist two types of rules in gaming according to literature. One is formal rules that are formally defined and written for gaming, and the other is informal, unwritten rules that are not formally expressed but need to be learned by the player to play the game [34]. If rules are not clearly defined, it will affect the gameplay and degrade the quality of experience felt by the player. Rules define how players move around the game and how they earn points to win the game. In [35], the authors review how gaming can be used for education by changing the play rules such that it engages the student in a hands-on learning activity.

3.1.2. Assets

Assets are different virtual properties (visual-audio components) that constitute the game, including but not limited to character models, animations, background music, sound effects, credits, items, avatars, etc. CloudyGame has been proposed as a new software architecture to share and manage various playing instances with on-demand game asset streaming on edge servers, enabling cloud gaming on the edge [36]. These contribute to improving the immersion and appeal of a game, providing a better experience for the player. The avatar customized by users has been shown as a virtual asset that captures the virtual identity of players in massive multiplayer online games [37]. In traditional games, these assets are owned by the game operator, while in blockchain-based gaming, assets can be owned by the players. Monster is a scheme that utilizes deep learning and generative artificial intelligence models with the Pixel2Mesh architecture to automatically generate 3D gaming assets that would otherwise require a graphic designer [38].

3.1.3. User-produced elements

In contrast to traditional games, in which all assets are created by the game creators, user-produced elements are a new and emerging concept that allows participants to produce and share their customized creations within the game environment. Barbarossa is a user-generated content-driven pervasive role-playing game that introduces portability to pervasive games otherwise restricted to limited environments [39]. This is different in comparison to traditional games, where the players are restricted to a specific game. Moreover, this user-generated content has the capability to be collaboratively utilized in numerous games that encourage players to create new content. In [40], the authors propose a method to learn user quality-of-perception of cloud gaming utilizing features of user-produced elements like feature words of text. Examples of user-generated content are custom levels, mods, skins, characters, etc. that are not predefined by the game developer. There are instances in which entire new games have been created due to user-generated content. Examples are “Counter Strike” and “Defense of the Ancients”, which evolved from “Half Life” and “Warcraft III”, respectively [41]. User-produced content can be optimally collected on game servers, where the game creators can make real-time decisions based on user statistics derived from them [42]. Data collection should not negatively affect the gaming performance and should be collected with minimal overhead; therefore, real-time optimizing systems are more appropriate for data gathering [43].

3.1.4. Multiplayer functionality

Multiplayer functionality provides the opportunity for the players to interact with each other in real-time, either cooperatively or competitively, through a network in online multi-playing games. Research in [44] points out 4 networking aspects that should be satisfied for efficient multi-playing: networking resources like bandwidth and latency, communication architectures, scalability by parameterization, and security against cheating and vandalism. The level of multi-playing can vary from simple cooperation to large-scale battles. Features such as matchmaking, leaderboards, and voice can improve the overall multiplayer experience. In [45], a ranking system has been introduced to improve the user experience for massive multiplayer games like “League of Legends”. In multi-modal multiplayer gaming environments, speech input and multimodal gestures facilitate the user’s ability to interact collaboratively within the game [46].

3.1.5. Customization options

Customization options predefined by the game developer allow players to personalize their gaming experience based on their own playstyle and preferences. For instance, in character customization, players can create unique avatars by selecting different appearance options. In [47], researchers show that there is less association between avatar customization and cooperation or competition in game play, while these have a resemblance to social outcomes. In a war game, weapons and equipment can be customized. These further include a customizable user interface that allows adjustments in display options, audio preferences, etc. In interactive storytelling, a user-centric approach is recommended, which provides various customization levels for optimizing the gaming experience without being limited to technology attributes or medium characteristics [48].

3.1.6. Accessibility options

Accessibility options aim to strike a balance between players’ physical and cognitive abilities. A review in [49] shows that differently abled people find difficulties in games due to not receiving feedback, not having identification in in-game responses, and the inability to provide inputs from various input devices. These include adjustable difficulty levels, scalable text sizes, and colorblind modes, allowing the game to be played by a differently abled audience. To improve accessibility, game developers often use subtitles and audio descriptions. For instance, in [50], a user-friendly interface with visual cues and icons is designed for gaming that can be projected to a screen or use touchscreen technology, reducing the struggle of interacting while playing board and card games.

3.2. Architecture of a Game

3.2.1. Game client

The game client is the application program with which the players interact directly, which is installed on the player’s device and responsible for rendering graphics, playing sounds, and handling user input. In a performance evaluation done by using the game Ms. Pac-Man, it has been found that frame rate and distortions of display are critical factors for gaming using thin clients, while they have different degrees of robustness to network impairments [51]. The game client communicates with the game server to exchange data like player actions, game state updates, player information, etc. The data-transfer channel among the game server and the client should meet the high-end quality of service requirements for the purpose of the game to be productive [52]. Another study done on the performance of the client in mobile cloud gaming states that they can save energy by 30%, and bitrate and framerate affect the decoder’s resource consumption, with framerate having the highest effect [53].

Fig. 2 disseminates the hybrid client-server architecture that exists in multiplayer games.

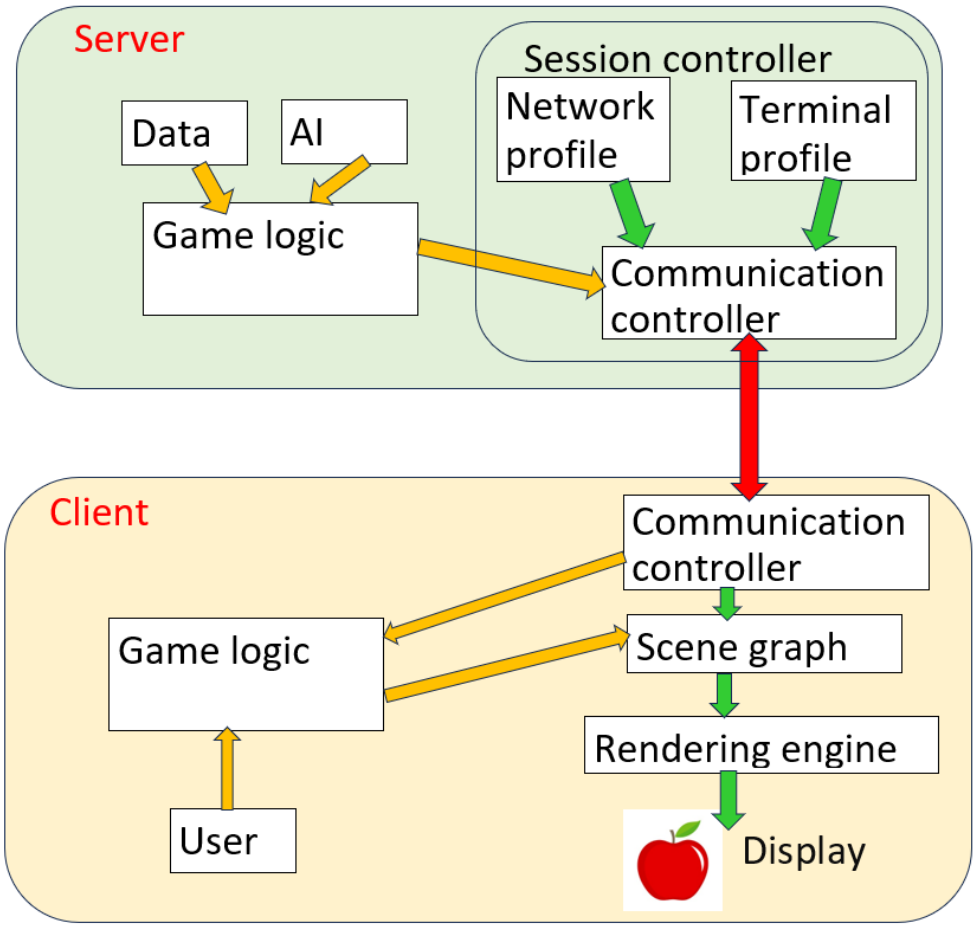


Fig. 2: Hybrid client-server architecture of multiplayer games.

3.2.2. Game server

The game server is responsible for managing the game world, processing game logic, and communicating between multiple clients. An algorithmic approach to server provisioning by using queuing theory and stochastic models in order to select server type and distribution of software has been studied in [54]. Moreover, in [55], a cloud mobile gaming approach by shifting the workload of gaming engines to cloud servers while mobile devices only provide gaming commands to servers has been used and tested for user quality of experience. Furthermore, it stores the authoritative version of the game state so as to warrant consistency among all clients. In order to prevent authentication problems and unauthorized use of copyrighted content, server abandonment should be prevented in order to protect the rights of game stakeholders [56]. Not only that, it handles physics simulation, game rule enforcement, player connections, and matchmaking. In mobile cloud gaming, the network should result in low-latency communication while also maintaining reliable communication, since gaming involves the transmission of video and audio frames [57]. Therefore, link-lifetime-based routing approaches are more suitable to be deployed in such environments that take into effect the dynamics of the mobile network while also minimizing latency [58].

3.2.3. Monitoring and analytics tools

Monitoring tools can track the performance and health of game servers in order to identify if any issues exist. Research in [10] has shown that using a multi-level game theoretical model, subordinates and principals at organizational levels should have explicit contracts for monitoring and sanctioning, where agents are players. Analytics can provide an insight into the player's behavior so that the game can be updated dynamically to suit the player's behavior. Research in [59] shows that game and learning analytics are less suitable for analytics in serious games and that serious game analytics are required to show actionable insights to retrain or remediate playing learners. Moreover, similar measures and gameplay action behavior profiles with n-grams to preserve navigation of directional paths have been evaluated for differentiation of user profiles in serious games [60].

3.3. Gaming Concepts

3.3.1. Serious games

Serious games are aimed at ambitions beyond enjoyment, like education, demonstration, training, etc. By simulating real-world scenarios, they further aim to bring behavioral changes in the participants of the game subsequent to playing the game. Serious games can simulate real-world situations that may be difficult to implement in reality due to safety

concerns, cost, time consumption, etc., while aiming to develop the player's skills [61]. Furthermore, they incorporate game mechanics and elements while aiming to achieve a specific purpose. They can be used to improve the psychological and physiological sensory motor functions and change the nutritional factors of elderly people in rehabilitation [62]. An investigation into the impact of serious games on medical training indicates that the game has motivated experienced medical students; however, it is counter-productive for new students [63]. A serious game designed for disaster preparedness of earthquakes' behavioral response and evacuation has shown that the game play has increased knowledge about evacuation and self-efficacy [64].

3.3.2. *Gamification*

Gamification is the principle of applying game design principles and elements in non-game contexts with the objective of enhancing engagement and motivation. It integrates game-like features such as points, badges, leaderboards, and challenges into non-game-related activities in order to motivate the desired activity. For instance, a study done using the Kano model shows that fitness applications that reward users based on completing workouts have a high degree of user satisfaction [65]. Furthermore, systematic reviews suggest that language learning platforms with progress tracking using virtual reality and gamification indeed help to learn foreign languages effectively, especially the English language [66].

3.3.3. *Exercise gaming*

Exercise gaming demands physical activity from the players, promoting physical fitness of the players while at the same time providing entertainment. In a study done among older adults aged more than 50 years, they preferred virtual augmented exercise gaming over traditional exercises, despite not having evidence for an association between physical fitness and game performance [67]. These often involve full-body tracking and motion controllers. "Exercise My Game" has been shown as a platform to transform a given traditional action game into a full-body motion game by mapping control input into game action and mixing input feedback with the game's interface by considering game requirements [68].

3.3.4. *Simulation gaming*

Simulation games replicate real-world systems in a virtual environment. Players can take on different roles, such as controller, manager, and designer of diverse elements like cities, vehicles, etc. A comparative study done on two flight simulation games, "Falcon 4.0" and "Microsoft Flight Simulator", shows that Falcon participants have shown short and long transfers in flight evaluation metrics, proving that the game has fortified them for common and special military activities [69]. In the planning profession, the "SimCity" game simulator has been used to provide a dynamic decision-making surrounding for students to develop problem-solving skills and crafting, despite not being a tool that helps to achieve learning outcomes in all students [70].

3.3.5. *Social games*

Social games are games that promote social interaction and are played with cooperation or competition with other players. In social games, according to [71], challenges, communication, providing gifts, meeting friends, and friends bars have been identified as techniques that improve the social aspects of social games. "World of Warcraft" has been shown as a game that has social aspects that allow players to have social relations and provide social game elements such as grouping with social networks [72].

3.3.6. *Narrative games*

Narrative games involve delivering narratives or character-driven experiences, where players make choices that influence the direction of the story, leading to various branching paths. Research has shown that game mechanics in narrative games provoke the game players to act in a way that helps in the construction of engaging stories out of the player's mind by creating tension using spatial conflicts, characterization, and moral dilemmas [73]. In the narrative game "Life is Strange", non-violent interpersonal conflicts are encouraged and allowed to be experienced by game mechanics that do not emphasize winning or losing, but rather putting into practice ethical exploration and empathy [74].

3.4. Game Ecosystem

The game ecosystem is graphically disseminated in Fig. 3.

3.4.1. *User*

Users are the individuals who interact with the game and have their own set of skills and preferences. Within game user research, it involves studying the interaction among players and their surroundings by using the interaction between humans and computers, the study of media, and social science

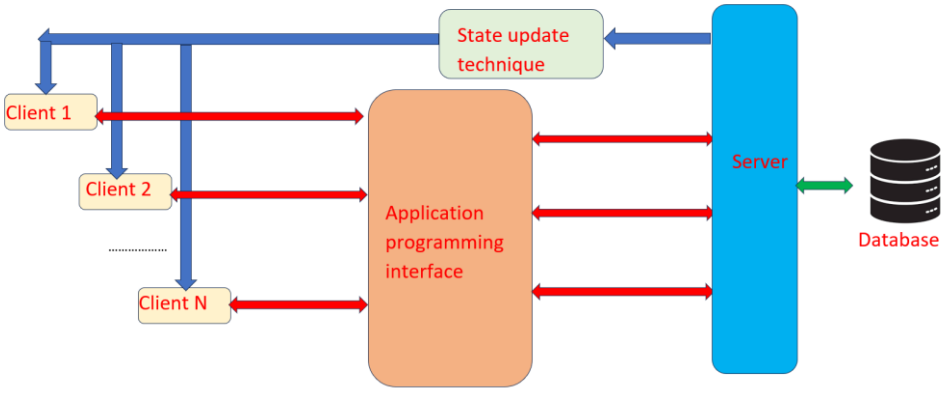


Fig. 3: Cloud-based multiplayer game ecosystem.

in diverse game types, not limited to entertainment games [75]. However, some computer game users have been reported to show addiction to it, characterized by excessive use of gaming such that it negatively interferes with common tasks, and these users have shown lower dopamine levels to gaming-related stimuli [76].

3.4.2. Interface software and device

Interface software and devices are the mediums through which users interact with the game. In [77], a hand-gesture-based interface to interact with the game in a public setting using vision algorithms to identify the complex gestures has been studied. Hardware interfaces include gaming consoles, personal computers, and mobile phones. The software interface provides the graphical and audio interfaces required to navigate menus, control characters, and interact with the game environment. However, in pervasive gaming, users are not restricted to traditional graphical user interfaces or computer screens, but are supported by tangible user interfaces in which players can grasp and move real-world objects for interaction with the game [78].

3.4.3. Backend platform

The backend platform is comprised of infrastructure and services that support online functionality and connectivity to the game, such as databases, servers, networking protocols, matchmaking algorithms, etc., enabling multiplayer gameplay, social interactions, downloadable content, etc. In a study that assessed the backend side of massive multiplayer online gaming, it was shown that the infrastructure-as-a-service tier performs superiorly to the platform-as-a-service tier in cloud platforms in terms of real-time latency [14]. Moreover, game-backend-as-a-service has been proposed with the development of gamification as a service in order to provide cross-platform game services embedding game features like leaderboards and remote storage [79].

3.4.4. Game

The game contains the software, content, mechanics, and design elements that define the player experience. A game can provide excitement, fear, happiness, security, insecurity, or indifference as an objective feeling to the end-users. In order to deliver a particular objective feeling to the user, there are numerous game categories such as action, puzzle, shooter, fight, flight, sports, strategy, etc. The author in [80] argues that gameplay and interactivity are distinct features, while gameplay is associated with emotions and player experience. Game play can consist of narratives, immersive worlds, and rewarding progression systems, while it can be aligned with a game story to enhance the player experience by enhancing immersion and improving player motivation. In [81], authors proposed machine learning to classify game events in order to discuss the relationship among diagnosed event clusters and patterns in game design to incorporate player personal profiles for analysis. Machine learning can be effectively used to classify game events and for other classification or regression problems related to gaming [82].

3.5. Game Mechanism

3.5.1. Game loop

The game loop is the backbone of the game, which is a continuous loop that runs throughout the game's lifetime. The main functions of this are input handling, updating, and rendering graphics. This loop starts by gathering input from the player, such as key strokes, joystick inputs, etc., and the game updates its internal state based on the received input by considering other factors such as physics calculations, game logic, etc., in order to render the updated state to the screen. Work in [83] proposes the simultaneous parallel operation of a graphic processing unit and a central processing unit to process game loop activities using Lua scripts to choose the best processor for a given task by considering performance over time. Moreover, this loop is iteratively run throughout the game to provide an illusion of real-time gameplay. Some have proposed the gameplay loop for educational game design using knowledge from didactics, taking into consideration curriculum and mediation, and player-centric design [84]. Thus, knowledge generation models like machine learning tools can be effectively utilized to extract knowledge from the game loop for improving game design [85].

3.5.2. Game authentication

Authentication is critical in online games to identify the users they claim to be and provide permissions to use the game's features. In order to achieve this process, users need to log in, and once logged in, they are provided with an authentication token that uniquely identifies a player session. For subsequent transactions between the game client and server, this authentication token is used for user validation. By criticizing weaknesses in single-time user authentication, continuous authentication has been realized in gaming environments with the aid of mouse movement tracking acting as credible reliability markers to authenticate users in real-time and has shown good performance compared to static authentication [86]. Some have proposed a novel interactive framework that necessitates players to pursue a gaze pattern in order to provide authentication to the game that prevents early-prepared videos or images from deceiving the authentication system [87].

3.5.3. Virtual assets

Virtual assets are items or currency within a gaming environment that are really valuable to the game players, such as weapons, armor, virtual currency, etc. However, it has been reported that some have misused virtual assets, such as virtual currencies, in multiplayer online games where cybercriminals have used them to send virtual currencies to other cyber-criminals, known as money laundering [88]. These assets are usually created by game developers using 3D modeling software and are stored in the game database along with their metadata [89]. Players may buy or sell virtual assets during gameplay in agreement with game mechanics, either using virtual or real-world currencies, allowing monetization. Recently, researchers have proposed photogrammetry, a technique to generate photorealistic 3D models, for generating 3D models in gaming systems [90].

Table 1 disseminates conventional literature on the gaming idea.

Table 1: Conventional literature on the gaming idea.

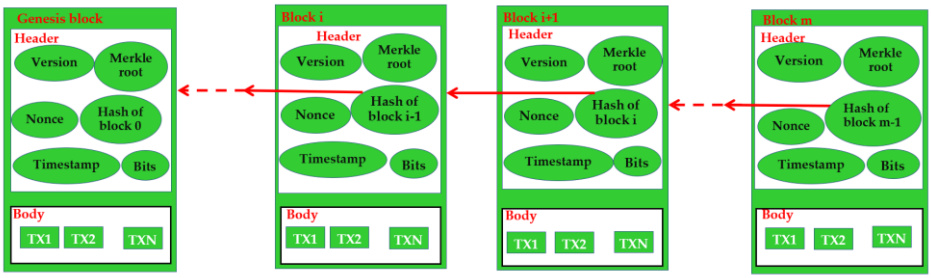
Gaming aspect	Conventional literature	Strategy	Performance
Game rules	Authentic design [35]	Changing play rules for learning	Not applicable
Game assets	CloudyGame [36]	Streaming of assets dynamically and sharing game instances	70-80% lower memory and computational resource requirement, scalable
	Virtual assets [37]	Study role of game character in massive multiplayer online games	Offer implications to business field
	Monster [38]	Deep learning with Pixel2Mesh architecture	Reduce intervention and expenditure for 3D game object construction
User generated elements	Barbarossa [39]	User generated content driven pervasive role-playing game	Improves user quality of experience
	CGQoE [40]	Predicting cloud gaming QoE using user produced elements using 14 feature words	Able to predict QoE and can analyze factors affecting it
Multiplayer functionality	Multiplayer computer games [44]	Present 4 networking aspects for efficient multi-playing	Discuss and analyze the aspects
	Sensitive matchmaking [45]	A ranking system to improve user experience	Applicable to League of legends and can be generalized
	Multimodal multiplayer tabletop gaming [46]	Players interact directly using speech and hand gestures	Multimodal gestures and speech enhance collaborative interaction
Game customization	Avatar customization [47]	Cooperative gaming and avatar customization	In game cooperation and competition have an effect on social outcomes
	Interactive storytelling [48]	Customization levels for optimizing gaming experience	Have analyzed on interactive storytelling
Game accessibility	Interaction with accessibility [50]	A user-friendly interface with visual cues and icons	Reduces the struggle for interacting for playing board and card games
Game client	Thin client gaming [51]	Evaluate performance of game Ms. Pac Man using 3 thin clients	Frame rate and distortions of display are critical factors for gaming
	Mobile cloud gaming performance [53]	Cloud gaming platform to do experiments on actual mobile clients	Save energy by 30% and bitrate and framerate affect decoder's resource consumption
Game server	Server provisioning [54]	Queuing theory and stochastic models	Computationally efficient and cost optimal
	Cloud server based mobile gaming [55]	Develop a MGUE model and a prototype to measure user experience	Validate MGUE model and characterize user experience
	Server authentication [56]	Propose ideas to prevent server abandonment	Protection measures can protect access to legally purchased items
Game monitoring and analytics	Monitoring and gaming [10]	Multi-level game theoretical model with monitoring and sanctioning	Has applied the model to the financial service industry
	Serious game analytics [59]	Analyze and discuss on the perspective of serious game analytics	Game and learning analytics are less suitable for analytics in serious game
	Evaluation of similarity measures [60]	Differentiate players based on GAD profiles using similarity measures	Similarity measures used in combination are more effective
Serious games	Prevention and rehabilitations [62]	3 criteria to evaluate effectiveness of serious games	Improve the psychological and physiological sensory motor functions of elders
	Medical training [63]	Five empirical studies to assess serious games	Motivated the experienced medical students
	Disaster preparedness [64]	Training done in Auckland city hospital using immersive virtual reality	Increased the knowledge about evacuation and self-efficacy
Gamification	Fitness application [65]	Reward users based completing workouts, Kano model for evaluation	High degree of user satisfaction
	English language learning [66]	Virtual reality and gamification	Help to learn foreign languages effectively
Exercise gaming	Virtual augmented exercise gaming [67]	Tested 3 versions of VAE	Preferred for virtual augmented exercise gaming over traditional exercises
	Exercise my game [68]	Full body motion game by mapping control input into game action	Converted Portal 2 into exergame "Sportal"
Simulation gaming	Transfer of training [69]	A study done using 3 groups: Falcon, Microsoft FS, and control	Falcon 4.0 players have shown short and long transfer in flight evaluation metrics
	SimCity [70]	Have evaluated the learning of students using SimCity	Allow students to develop problem solving skills and crafting
Social games	Social mechanics [71]	Analyze social mechanics in social games	Different mechanisms were found to encourage social activity
	World of warcraft [72]	Explore social relations and social game elements impact experience	Design suggestions to enhance user experience are proposed
Narrative games	Narrative game mechanics [73]	Conduct 3 case studies	Provoke the game players to act and create tension
	Life is strange [74]	Detailed case study of representations of how game mechanics allow playing of interpersonal conflicts	Non-violent interpersonal conflicts are encouraged
Game user	Game user research [75]	Learn about interactions between users and game	Present a case study on methods
	Game addiction [76]	Studied interactions for a motorbike riding game	Game users have shown excessive use of gaming
Game interface	Playing into wild [77]	Hand gesture-based interface	Obtained results for "Tortellino X-Perience"
	Pervasive gaming [78]	Tangible interface by physically grasping and moving	Developed framework as part of a game design course
Game backend	Multiplayer game backends [14]	Evaluate suitability of cloud platforms for developing backend of MMOG	infrastructure-as-a-service tier performs superior to platform-as-a-service tier
	GBaaS [79]	Game-backend-as-a-service for cross platform game services	Survey some GBaaS
Gameplay	Gameplay emotions [80]	Argue gameplay and interactivity as distinct features	Gameplay is associated with emotions and player experience
	PPAX [81]	Gameplay experience assessment with machine learning	Discuss relationship among events and game design patterns
Game loop	Adaptive game loop [83]	Game loop activities using Lua scripts to choose the best processor	Find the optimum processor for grouped tasks
	Educational game design [84]	Player centered design using knowledge from didactics	A case investigation of a literacy game shows the application of gameplay loop method
Game authentication	User identity [86]	Mouse dynamics for continuous authentication	Good performance compared to static authentication
	Live authentication [87].	Gaze pattern for authentication	Prevents early prepared videos or images from deceiving the authentication system
Virtual assets	Photogrammetry [90]	Generate photorealistic 3D models	Discuss possible areas of application

4. AN OUTLINE ON BLOCKCHAIN

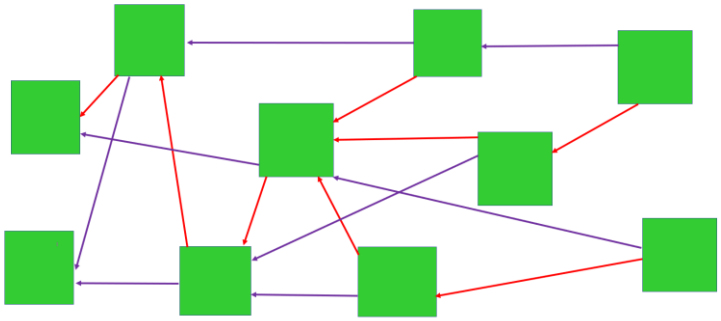
Blockchain is a dispersed ledger scheme that securely logs transactions across a network of computers [91]. The records are immutable, making it not possible to alter or delete them without the consensus of the participants, further making the blockchain transparent [92].

4.1. Design

In a linear blockchain, there is a successive block continuum leveraging cryptographic hash links [93]. A non-conventional blockchain deviates from the linear blockchain, where transactions are not grouped into blocks but individually linked to multiple previous transactions [94]. This structure makes them scalable and has a high throughput,



(a)



(b)

Fig. 4: Blockchain designs (a) Linear, (b) Non-conventional (Graphchain).

as transactions can be processed concurrently. There exist also hybrid structures that combine the features of linear and non-conventional blockchains [95].
Fig. 4 disseminates linear and non-conventional blockchain architectures.

4.2. Consensus

Consensus is the mechanism by which blockchains reach agreement on the validity of transactions in order to maintain their integrity [96]. In traditional consensus approaches, miners compete to solve a complex puzzle, and the first to solve it gets the opportunity to add the next block [97]. Other consensus approaches include those based on the number of coins held and ability to stake, the holding of high reputation and authority, the ability to allocate disk space, etc. [98].

4.3. Cryptography

Cryptographic algorithms are utilized to maintain the security and tamper-proof nature of transactions, unlike data aggregation [99]. In hash functions, input data produces a fixed-size character string, which is used to ensure data integrity and create unique identifiers for blocks [100]. A digital signature, which is realized using public-key cryptography, is used to warrant the authenticity of transactions by using a private key for signing the transactions and a public key to verify the signatures [101]. Cryptographic tokens are used to represent assets, ownership, and ownership transfer in decentralized applications [102].

4.4. Smart Contracts

In smart contracts, terms of agreement are directly written into the code that can execute itself when predefined conditions are met [103]. Thus, these can be used to automate the execution of agreements, eliminating the need for intermediaries, reducing the risks of fraud and manipulation, and further strengthening the high degree of trust thanks to blockchain's immutable features [104].

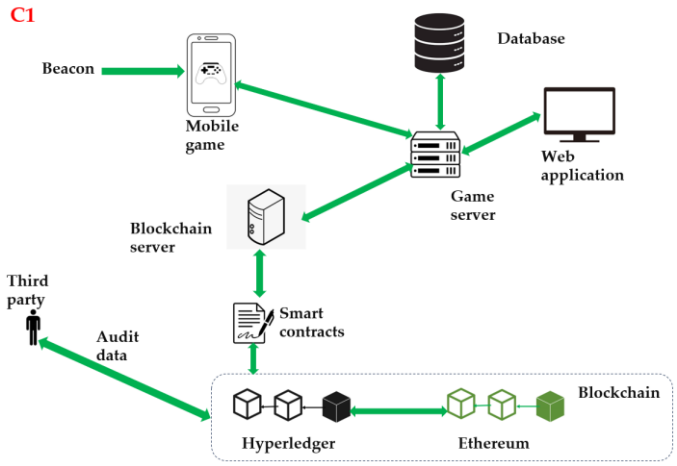
5. BLOCKCHAIN-BASED GAMING

5.1. Reflection

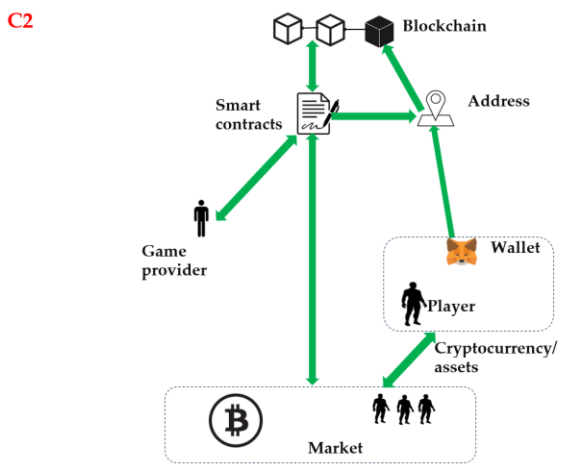
Centered around this investigation, the blockchain-stemmed gaming reflection can be ranked into the nether 11 tasks**.**

- Game auditing (C1)
- Game incentivization (C2)
- Gamification (C3)
- Cooperative game play (C4)
- Game fraud prevention and fair play (C5)
- Game DApps with extendibility (C6)
- Game asset ownership protection and asset transactions (C7)
- Game user-produced elements security (C8)
- Game credential verification (C9)
- Game rule transparency (C10)
- Crypto gaming (C11)

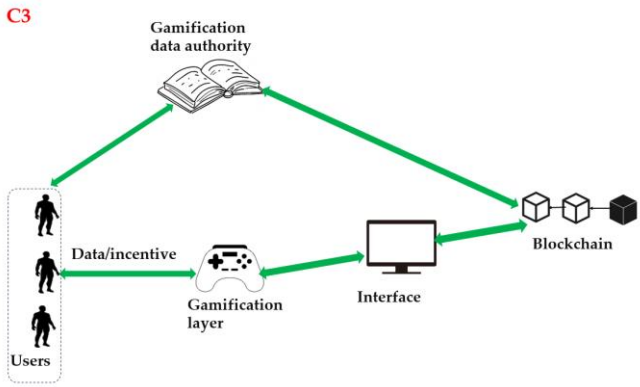
Fig. 5 illuminates the reflection of blockchain-stemmed gaming.


C1
Beacon
Mobile game
Database
Web application
Game server
Blockchain server
Third party
Audit data
Smart contracts
Blockchain
Hyperledger
Ethereum

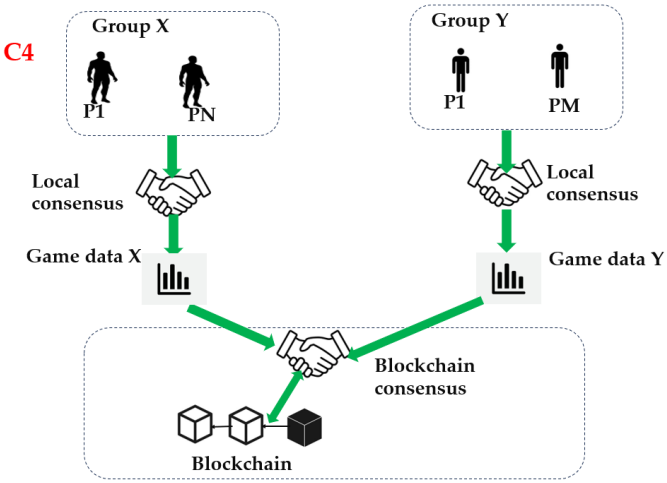
(a)


C2
Blockchain
Smart contracts
Address
Game provider
Wallet
Player
Cryptocurrency/ assets
Market

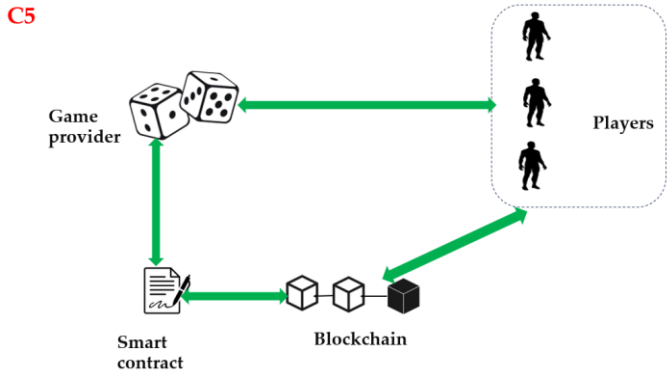
(b)


C3
Gamification data authority
Blockchain
Data/incentive
Gamification layer
Interface
Users

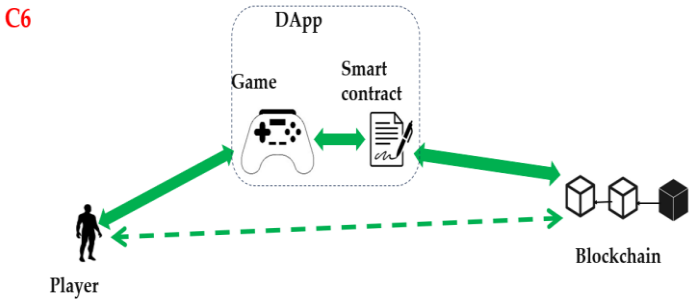
(c)


C4
Group X
P1
PN
Group Y
P1
PM
Local consensus
Local consensus
Game data X
Game data Y
Blockchain consensus
Blockchain

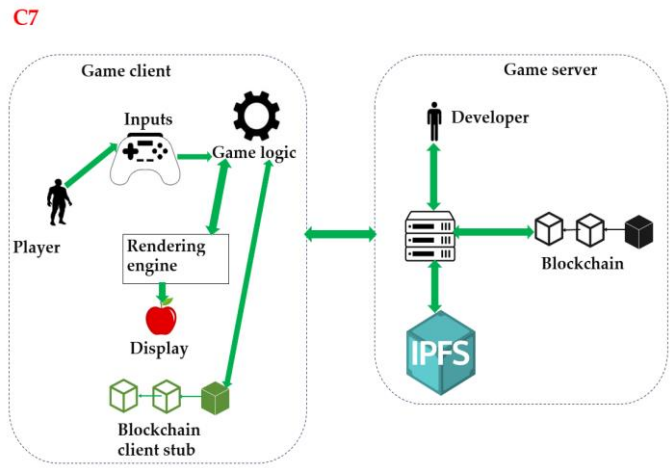
(d)


C5
Game provider
Players
Smart contract
Blockchain

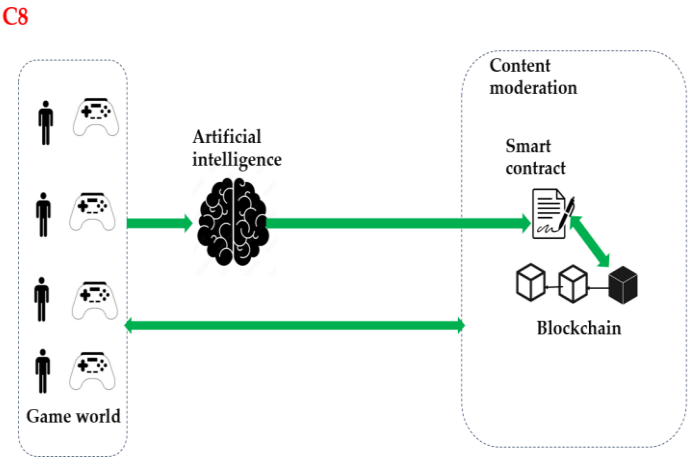
(e)


C6
DApp
Game
Smart contract
Player
Blockchain

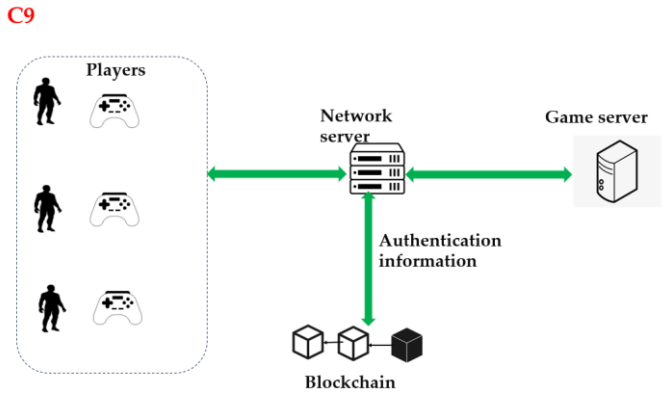
(f)



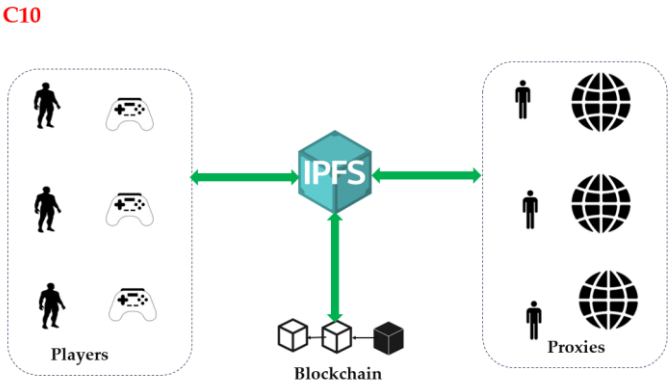
(g)



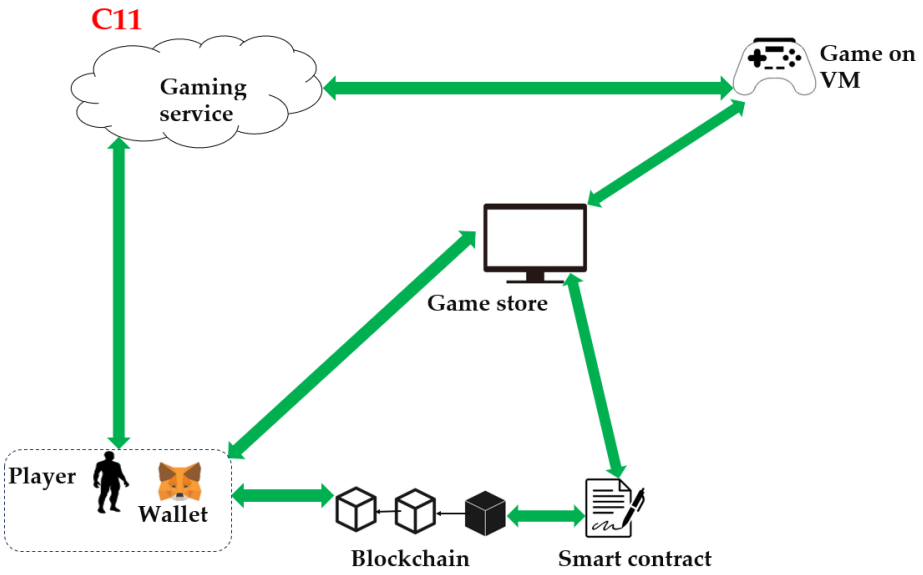
(h)



(i)



(j)



(k)

Fig. 5: Reflection of blockchain-stemmed gaming (a) C1, (b) C2, (c) C3, (d) C4, (e) C5, (f) C6, (g) C7, (h) C8, (i) C9, (j) C10, (k) C11.

5.2. Review on Blockchain-based Gaming

5.2.1. Game auditing

For an IoT scavenger hunting mobile game that facilitates users to interact with real-world locations where player-received rewards are stored on the blockchain as Non-Fungible Tokens (NFTs) that can be subsequently utilized for trading virtual assets in a secure and auditable manner [20].

5.2.2. Game incentivization

In [105], blockchain (permissioned and permissionless) is applied in the internet of things in order to attract customers and retain them through in-game asset improved monetization by using personalized advertisements, where permissioned blockchain has resulted in improved throughput and delay performance while public blockchain has facilitated transparency and immutability. In blockchain-based gaming, the dealings between the game supplier and gamers can be modeled as a two-stage Stackelberg game where the virtual game resources are associated with the player's address and traded them using a second exchange market, where the model decides the game provider's optimal pricing scheme and the player's optimal utility while also considering blockchain gas fees [21]. In play-to-earn blockchain games where users play to earn cryptocurrencies in the form of digital labor, blockchain is utilized to reconfigure the capital-labor relationship, facilitating the financialization of labor; however, there is a precarity associated with volatile earnings and insecure contractual employment [106].

5.2.3. Gamification

Researchers have used a serious gaming strategy to gamify crowdsensing in a metropolitan water framework where the gamified environment provides entertainment while crowdsensing achieves water-linked problems where a distance-limited multi-depot vehicle routing problem has been evaluated, while the Hyperledger blockchain supplies the overall trust among stakeholders in crowdsensing [22]. Knowledge is modeled as triples, and knowledge retrieved from users is validated and included in the knowledge base by using a gamified crowdsourcing approach where users are rewarded for relying on their assistance for the knowledge verification procedure, and blockchain is availed to archive the user logs securely [107]. In order to increase human involvement in crowdsourcing for fake news identification, gamification has been blended with smart contracts to deploy the platform rules transparently with elevated trust [108]. Some have used gamification to increase user participation in vehicle parking, where the users report free spaces and obtain free parking time in return as a reward, while blockchain has been utilized to implement the process in a distributed and decentralized manner with collaboration [109]. In [110], the authors show how blockchain can be utilized in educational gamification to achieve security and transparency while also achieving the desired educational objectives. Similarly, GamiChain is an online education model that uses gamification for learning and playing, while blockchain is utilized to implement security in the system by creating a distributed storage algorithm in the blockchain [111]. Research in [112] depicts two problems in blockchain-based gaming systems, which are non-functioning user participation and unsustainability in the growth of assets, and proposes a generic stealth gamification model that contains a gamified layer in the decentralized applications to interface with the blockchain. Similarly, "Healthcare Game Blockchain" is a platform developed for game developers, healthcare providers, and patients to create serious games related to healthcare that can be used for patient treatment and healthcare analytics using big data analytics, where blockchain is utilized to improve the data sharing security on the platform [113].

5.2.4. Cooperative gaming

In research [114], reciprocal crowdsourcing is introduced, which is a decentralized cooperative crowdsourcing technique driven by blockchain to elevate trust among the participants who do collaborative work, where a blockchain game known as "Cell Evolution" is used to build cooperative game worlds. In order to reduce drawbacks in conventional consensus in peer-to-peer blockchain games without changing the game architecture, proof-of-play is a new consensus approach that has minimum intervention with game play, providing a decentralized architecture for gaming [115]. Moreover, this consensus approach has been utilized in peer-to-peer online games to generate an anti-cheating technique by providing positive rewards for players who act as intended and having other measures to tackle long-range attacks [23]. Alternatively, another research proposes a new consensus approach to be deployed in blockchain-based gaming known as proof-of-achievement that focuses on the number of activities accomplished within the game to achieve the consensus that is optimum for blockchain-based gaming [116]. In [117], blockchain is proposed for data sharing to maintain a secured scoring system for multiplayer games, which has been tested using the Unity game engine and Ethereum blockchain, where the score data transaction process is affected by blockchain gas-related variables.

5.2.5. Game fraud prevention and fair play

By utilizing the assistance of smart contracts and blockchain, the research in [24] customizes games with the least modification to game clients to manage game status at the servers by consensus mechanisms to check modifications to player assets, minimizing dishonesty and distributed refusal of service attacks in multiplayer online games. Similarly, "GiNA" is an approach for online peer-to-peer games to improve the security and authenticity of data communication by using a smart contract-rooted blockchain packet transfer for sensitive data, an off-chain encrypted packet transfer, and an Ethereum-compatible currency known as "GiCoin" to buy and sell assets [118]. Driven by the fact that games such as gambling games need to have a true random number generator without being manipulated by a centralized authority, research in [119] shows how blockchain can be utilized to achieve the preceding purpose of making the gameplay fair. Moreover, some propose a game-theoretic approach to protect randomness in blockchain-based games where agents bet on random event outcomes to align the incentives with low skewness [120]. Similarly, in another research, authors propose blockchain as a solution to manage the private random state in online multiplayer gaming in a decentralized

manner, thanks to its transparency and immutability features [121].

5.2.6. Game DApps with extendibility

The study in [122] proposes a methodology for creating decentralized apps with blockchain for blockchain-based crypto-collectible games that presents the specifications and application design process and finally compares them with guidelines. In research [25], authors propose smart contracts running on blockchain to implement loot boxes in video games and design a DApp that demonstrates the buying and unclosing of loot boxes, which has yielded improved transparency and trustworthiness compared to the traditional technique.

5.2.7. Game asset ownership protection and asset transactions

In a study that has implemented a mobile game using blockchain resource tokens and self-executing contracts, it was shown that the blockchain introduced features like trust and transparency, providing genuine asset ownership, have resulted positively towards gameplay by improving self-engagement and player retention [123]. Transaction Certification Authority is a distributed ledger scheme that provides an immutable and cryptographic framework for managing the generation and ownership transfer of digital assets by tracking transactions and maintaining a record of asset ownership [26].

"GameBlockchain" is a scheme that enables secure transactions leveraging non-fungible tokens, is open source, and provides the opportunity for game stakeholders to create and exchange game assets in a secure approach by recording critical operations on the blockchain [124]. A representation of blockchain gaming assets is utilized to enhance the data exchange in gaming and provide distributed data storage to be used by decentralized apps [125]. In a multiplayer tourism serious game, a visualized transaction scheme is implemented using the Ethereum blockchain by integrating it with the game engine to handle simulation of transactions among various characters in the game, and in this system, the gas price variable has affected the transaction process speed [126]. Furthermore, research in [127] demonstrates how blockchain can be utilized to reward users using fungible and non-fungible tokens in a 2D-game where metadata and token images are recorded in the IPFS.

5.2.8. Game user-produced elements

In [128], artificial intelligence and blockchain are combined to detect hate speech in user-generated content of online games known as "MetaHate" in the metaverse, where gradient boost-based AI detects hate speech while blockchain provides transparency and accountability.

5.2.9. Game credential verification

Work in research [27] shows how an alternative security mechanism can be deployed when the confidential security key is misplaced by using smart contracts for depositing game digital assets into them, accompanied by a set of authentication inquiries that can be deployed in cyber games to access players' accounts without the secret key. In order to avoid players' data from being manipulated, work in [129] proposes a decentralized LoRA WAN with a gateway system to secure the states in the game network, a hashing algorithm to tackle privacy, and smart contracts to cater to delay requirements and user authentication.

5.2.10. Game rule transparency

In research [28], in order to transfer the sole proprietorship of game rights and rules from game creators to a distributed approach and to prevent the game creators from changing the rules arbitrarily and asset prices, reward mechanisms, etc., a decentralized computation and token administration scheme using the Ethereum blockchain is proposed for game networks.

5.2.11. Crypto gaming

CryptoKitties is the first widely recognized blockchain-based crypto game. In CryptoKitties, a study has investigated the value construction scarcity among CryptoKitties token owners presented in the form of virtual cats and blockchain-proven ownership using DappRadar and Etherscan analytics [29]. In a cloud gaming system rooted in tokens, "CryptoArcade" is a system that utilizes cryptocurrency to provide a resource-aware pricing technique that prevents quality of service degradation while players further use smart contracts to trade tokens prior to gaming [130]. Similarly, "CloudArcade" is a token-driven cloud gaming scheme to provide resource-aware silent payments that use payment channels to improve the system's performance to protect users' payments on floating prices [131].

6. Review Investigation

6.1. Investigation of Individual Structures

Table 2 emphasizes the extensive investigation of blockchain-stemmed gaming structures in view of gaming qualities, blockchain qualities, and posted time.

6.2. Overall Investigation

Fig. 6 illuminates the dissemination of blockchain-stemmed gaming in view of gaming qualities, blockchain qualities, and posted time. As illuminated from Fig. 6a, C3 (blockchain-stemmed gamification) has the highest proportion (21.7%) of BC-stemmed gaming reflection, after C7 (16.2%), C4 (13.5%), C5 (13.5%), C11 (8.1%), C2 (8.1%), C6 (5.4%), C9 (5.4%), C1 (2.7%), C8 (2.7%), and C10 (2.7%). Likewise, in BC-stemmed gaming, 75.6% of schemes apply a linear blockchain, while 21.6% have a generic design and 2.8% have a non-conventional design, as illuminated in Fig. 6b. Furthermore, as illuminated from Fig. 6c, the majority of schemes (21.6%) have been created to apply unspecified consensus, succeeded by PoW (19.0%), PoW/PoS (13.5%), PoS (10.8%), and so forth. Ultimately, when examining the fluctuation of schemes associated with BC-stemmed gaming, as illuminated from Fig. 6d, it is apparent that the reflection has been launched by 2018, raised until 2021, condensed until 2023, and observed an increment in 2024.

Table 2: Investigation of blockchain-stemmed gaming structures

Reflection	Proposal	Blockchain design	Blockchain consensus	Smart contracts	Additional features	Performance	Year
Game auditing (C1)	Scavenger Hunt [20]	Linear	PBFT	Yes	BLE beacons, NFT	Estimate maximum active players	2020
Game incentivization (C2)	Mobile gaming [105]	Linear	PoS, PBFT	Yes	Cross game asset transfers	Improved throughput, delay performance	2021
	Loot box market [21]	Linear	PoS	Yes	Two-stage Stackelberg game	Game provider should adopt a conservative pricing scheme	2022
	Playing for keeps [106]	Linear	PoS	Yes	Play to Earn	Reflect an ongoing financialization of labor in gaming	2024
Gamification (C3)	Crowdsensing water [22]	Linear	PBFT	Yes	Vickrey–Clarke–Groves auction model	High trust in gamified scenario	2021
	Knowledge content validation [107]	Linear	PoW	Similar approach	Contribution-based rewarding	Validate knowledge content successfully	2021
	Fake news detection [108]	Generic	Generic	Yes	Octalysis	Increase public intention to use the platform	2021
	Gamified smart parking [109]	Linear	DPoS	No	Beacon information collection	Save time and money for parking	2019
	Student centered learning [110]	Generic	Generic	No	Gamification model	RPG game model suitable for increasing user motivation	2021
	GamiChain [111]	Linear	PoW/PoS	Yes	Agile development methods, IPFS	Support Merdeka campus program	2022
	Gamification in blockchain [112]	Linear	PoW/PoS	Yes	Gamification model	No performance analysis presented	2018
	Healthcare games [113]	Non-conventional	PoA	Yes	Big data analysis, patient tracking and treatment	User interface design and implementation approach provided	2023
Cooperative game play (C4)	Cell evolution [114]	Linear	PoD	Yes	Reciprocal crowdsourcing	Increased engagement due to full control of what is owned	2020
	Proof of play [115]	Linear	Proof-of-play	No	A new block writing procedure	Minimum game intervention and overhead	2019
	P2P game [23]	Linear	Proof-of-play	No	Anti-cheating mechanism	Proof of play is advantageous over PoW	2023
	Proof of achievement [116]	Linear	Proof-of-achievement	No	None	Optimized performance for blockchain games	2019
	Scoring system [117]	Linear	PoW	Yes	Unity game engine	Score data process affected by gas related variables	2021
Game fraud prevention and fair play (C5)	Real-time cheat prevention [24]	Linear	Simple majority	Yes	Optimization strategies	Minimize cheating and DDoS attacks	2018
	GiNA [118]	Linear	PoS	Yes	GiCoin, off-chain encrypted packet transfer	Improved game security and authenticity	2021
	Random number generation [119]	Linear	MBFT	Yes	Random number generation algorithm	Effective algorithm and good performance	2019
	Game theoretic randomness [120]	Linear	PoW	No	Game theory	Only slight skewness in distribution of random events	2019
	Private random state [121]	Linear	PoW	Yes	Six key entities, incentivization	Maintain prolonged random state	2020
Game DApps with extendibility (C6)	Secure DApp [122]	Linear	PoW	Yes	Consider application life cycle	Discuss several guidelines for smart contracts	2020
	Loot boxes [25]	Linear	PoW/PoS	Yes	Decision theory	Analyze DApp's accuracy, security, cost	2021
Game asset ownership protection and asset transactions (C7)	Blockchain game features [123]	Linear	DPoS	Yes	Blockchain asset tokens	Improve self-engagement and player retention	2022
	Digital game asset management [26]	Generic	Generic	No	None	Track ownership transfer of assets	2021
	GameBlockchain [124]	Linear	Custom	Yes	NFT	Able to create and trade assets	2022
	Video game data exchange [125]	Generic	Generic	Yes	Hashing	No performance analysis	2019
	Tourism serious game [126]	Linear	PoW	Yes	Multiplayer transaction system	Gas price variable has affected the transaction process speed	2020
	Mage Runner [127]	Linear	PoS	Yes	IPFS, tokens	A basic implementation is demonstrated	2024
Game user produced elements security (C8)	MetaHate [128]	Generic	Generic	Yes	Artificial intelligence	86.01% accuracy	2024
Game credential verification (C9)	Online game authentication [27]	Generic	Generic	Yes	Security questions	Security questions can cope with malicious behavior	2021
	Delay management [129]	Generic	Generic	Yes	LoRA WAN, hashing	Solve delay and untrusted network users	2018
Game rule transparency (C10)	Decentralized computing and NFT [28]	Linear	PoW/PoS	Yes	Decentralized computation, NFT, IPFS	Proxy based computation takes less time than game server	2020
Crypto gaming (C11)	CryptoKitties [29]	Linear	PoW/PoS	Yes	Breeding the queen bee concept	Investigated the value construction scarcity	2021
	CryptoArcade [130]	Generic	Generic	Yes	Prospect theory, cryptocurrency	Avoid QoE degradation, EUT players are more probable to buying	2022
	CloudArcade [131]	Linear	PoW	Yes	Cryptocurrency, resource-aware pricing	Good generality on QoE-driven application	2020

7. DISCUSSION

7.1. Advantages

7.1.1. Game rule decentralization

In traditional games, the game rules are defined by the game creators, and they have sole proprietorship over them. In blockchain-based games, the game creators lose the sole proprietorship, and game rights and rules are implemented as a distributed system with the approval of peers. This can indeed prevent game creators from having sole centralized control over in-game asset prices, rules, and reward mechanisms. On the other hand, blockchain-based gaming is player-driven, meaning that centralized authority is nullified by the decentralized blockchain approach, preventing manipulation by the central authorities. Indeed, in these systems, it facilitates the players and developers to interact and come to an agreement regarding rules, prices, reward mechanisms, etc.

7.1.2. Better game authentication

Smart contracts that execute upon meeting certain conditions can be deployed in blockchain-based gaming systems to reinforce game authentication and access control. Moreover, they can also be used as a secondary mechanism for game players to authenticate themselves if the primary mechanism, such as the private key, is lost. Due to blockchain, identity theft and impersonation can be minimized, as player identities can be stored as digital immutable IDs in the blockchain.

Blockchains replace traditional game authentication with decentralized authentication without needing intermediaries, reducing centralized authentication vulnerabilities such as hacking attacks. Blockchain-based gaming also caters to cross-platform authentication, where players access their accounts and game assets across multiple games and platforms.

7.1.3. Secure game asset ownership transfer

In ownership assignment, the digital identifier of the game player is associated with in-game assets. Trusted asset ownership protection can lead to higher player retention since players feel more protected about their asset ownership. In blockchain-based games, ownership regarding assets can be recorded on the blockchain so that it cannot be tampered with once recorded, preventing third parties from claiming false ownership. In these systems, the game assets are typically represented in the form of NFTs on the blockchain that are unique to each asset and easily verifiable, allowing players to have true ownership and control over the assets. This facilitates users to easily trade assets, and in those instances, the transfer of ownership will be recorded on the blockchain, providing ownership of the asset to the new owner.

7.1.4. Facilitate fair play

Cheating is a form of misconduct in computer gaming where players may take secondary measures, avoiding or overriding game rules, to win the game. Due to blockchain, the game servers can monitor the game status by using consensus approaches to check modifications to player assets, preventing cheating. Moreover, cryptographic techniques can be incorporated for off-chain storage along with in-chain storage of sensitive data to enable fair play. Moreover, in order to maintain true randomness in gaming, blockchain can be deployed, preventing manipulation or biasedness from centralized third parties and facilitating fair play, like in the case of gambling. Furthermore, in multiplayer online games, the private random state can be maintained owing to the immutable and transparent features of the blockchain. Finally, consensus approaches can also be incorporated to reward good players and punish players who cheat.

7.1.5. Trusted and secure gameplay

In cooperative game worlds, trust is an important parameter that can be protected due to the characteristic features of blockchain. In such instances, crowdsourcing can be implemented with the aid of blockchain, facilitating trusted collaboration. Moreover, novel consensus approaches suitable to be deployed in blockchain-based games, such as proof-of-play and proof-of-achievement that reward players based on game progress and achieve collective approval, can be effectively utilized to increase the security and trustworthiness of the game. Moreover, in multiplayer games, blockchains can enable tamper-proof recording of the scoring system, preventing third parties from manipulating the score and improving the trust and security of the gameplay.

7.2. Asperities

7.2.1. Security vulnerabilities of blockchain games

A case study shows that even though blockchain games are relatively more secure than non-blockchain-based gaming solutions, they can still have security vulnerabilities [132]. Specifically, smart contracts that are deployed on blockchain are known to have vulnerabilities where attackers can hijack the contract, such as in the event of calling a “fallback” function. These vulnerabilities can exist in different layers, ranging from virtual machine design to Solidity language. If an intruder obtains entrance to the private wallet of a blockchain and if two-step verification does not exist, he can further penetrate into the game server and may take control of game assets. Furthermore, due to these vulnerabilities, attacks like cookie replay, injection, cross-site scripting, brute force attacks to crack authentication, etc.

7.2.2. Crypto games imaging players as financialized subjects

According to a study conducted on crypto games, they are known to imagine players as financialized subjects using risk and investment as solutions to economic problems [133]. This can shift the focus of gaming experiences from objective feelings like entertainment, fear, etc. to opportunities for making profit. This can further destabilize the cryptocurrency market as players tend to be engaged in trading and business activities rather than playing and enjoying the game. Moreover, players with high financial capability may get the opportunity to buy rare assets and win the game, while fluent players who are less economically capable may not get that opportunity and thus may lose the game. This practice can lead to pay-to-win implementation scenarios where game developers design the game so that players who spend money are more capable of winning.

7.2.3. Low balance in gaming costs, supplies, and wealth

Relying on a study done regarding the rise and fall of CryptoKitties, it has been found that the imbalance in the game supply of assets, gaming cost, and revenue, and the

hiatus among wealthy and penniless gamers, has contributed towards the downfall of the game [134]. When the game costs do not tally with the supplies and wealth, it can create an

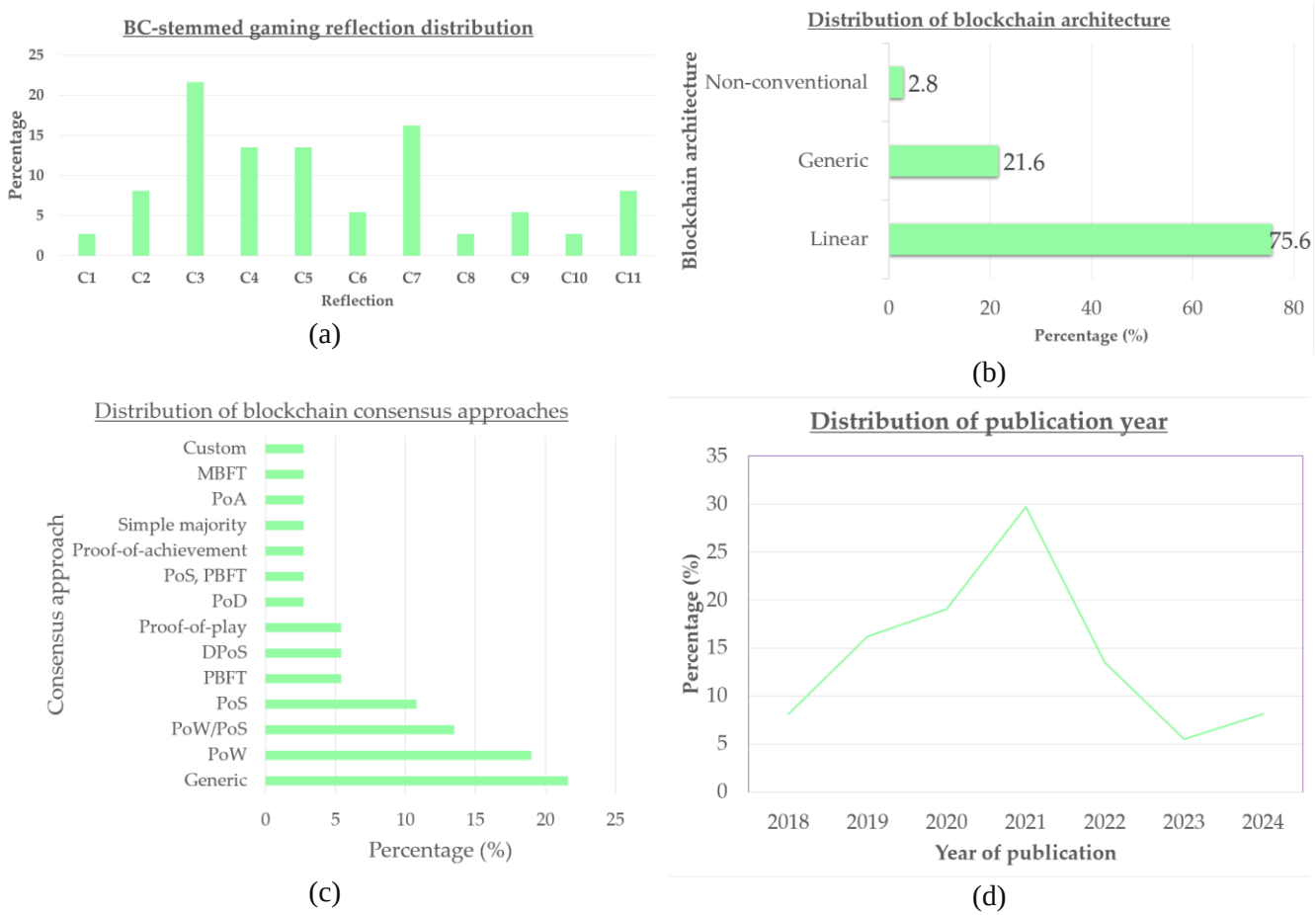


Fig. 6: Overall investigation (a) BC-stemmed gaming reflection, (b) BC design, (c) BC consensus, (d) Distribution time.

economic imbalance where the higher-wealth players may get an advantage over the low-wealth ones. Moreover, if the costs of achieving in-game assets are very low, it can negatively affect gaming by diminishing the player's long-term engagement within the game. On the other side, if the in-game assets or currency are much higher than the demand, it can lead to asset inflation, making them less valuable and making it challenging for players to achieve game goals.

7.2.4. Additional communication overhead in gaming

In multi-player online games, there is a huge load of information transmitted among the players and game servers. When blockchain is incorporated into such a scenario, the communication burden is even greater, as it causes additional communication for distributed transaction creation, verification, and consensus processes. Due to this, it can result in increasing the overall latency of the system, degrading the real-time effect of gaming and the quality of service. Moreover, this can further result in a requirement for higher communication bandwidth to maintain the quality of service. Thus, users with slower internet connections will be easily penalized.

7.2.5. Higher gaming cost

Owing to the incorporation of blockchain, the gaming cost has naturally increased. One of the reasons for this is the increase in communication overhead, which makes communication more expensive compared to traditional gaming. The other main cost is the blockchain transaction cost since every blockchain transaction causes transaction fees known as gas fees in the Ethereum blockchain. These costs are avalanched in games that involve a high degree of in-game asset transfers and interactions, like massive multiplayer online games. Thus, this higher cost can limit players from engaging in blockchain-based games compared to traditional gaming.

8. Conclusion, Offers, and Coming Ways

In this investigation, we investigated gaming features, the architecture of a game, gaming concepts, the game ecosystem, and game mechanisms**.** Afterwards, with an outline of the blockchain structure, we investigated blockchain-stemmed gaming**.** Centered around this investigation, we understood blockchain-stemmed gaming reflection within 11 tasks: game auditing (C1), game incentivization (C2), gamification (C3), cooperative game play (C4), game fraud prevention and fair

play (C5), game DApps with extendibility (C6), game asset ownership protection and asset transactions (C7), game user-produced elements' security (C8), game credential verification (C9), game rule transparency (C10), and crypto gaming (C11). Likewise, we extensively investigated the selected articles regarding 11 tasks of reflection, gaming- and blockchain-linked qualities. Finally, we exposed the advantages and asperities to the reflection of blockchain-stemmed gaming.

This inspection improves the conventional literature by presenting conducive knowledge connected with blockchain-stemmed gaming**.** This can guide the chances for the investigators to derive the conventional tides and differences in blockchain-stemmed gaming to fund subsequent research.

Centered around the asperities identified, the following offers can be extended to shrink them.

- The smart contract codes deployed in blockchain games need to be properly audited before actual implementation to detect any vulnerabilities that exist within the code. Specifically, auditors need to check for every possible situation of inputs and conditions that the code may run in order to detect the vulnerabilities. Further, they need to do formal verification, code feature matching, and symbolic execution.
- Blockchain-based games should not be designed entirely using a pay-to-win model, even though in crypto games it involves trading in-game assets among players. The game design should be aligned such that higher fluent players tend to win the game rather than those who buy in-game assets. In order to reduce this gap, the performance gains gained through game assets can be reduced.
- The blockchain games should maintain a good balance between gaming costs, supplies, and wealth because it determines the success of the game. The game needs to be engineered with the scarcity of assets principle in mind, where there is a scarcity of assets and players engage in different activities to earn assets and ultimately win the game. The game designers should avoid setting in-game asset values too high or too low and should set an optimum price after a feasibility study to match the player's wealth and skills.
- In order to overcome the difficulty of high communication overhead due to blockchain, system designers can think of alternative blockchain architectures and consensus mechanisms that incur lower communication overhead than a traditional linear blockchain deploying proof-of-work consensus. Moreover, robust communication techniques with data compression can also aid in reducing the communication overhead. Moreover, transactions can be offloaded from the blockchain while keeping only references in the blockchain to reduce communication overhead.
- To reduce gaming costs, in-game assets can be tokenized, allowing players to own their digital items, which can allow them to trade assets over multiple game platforms, reducing the costs of acquiring in-game assets. Deviating from the pay-to-win model, play-to-earn mechanics can be implemented in the blockchain-based game design, allowing players to engage in the game and rewarding them based on their positive engagement, allowing them to earn to rectify the gaming costs.

First, a coming way to develop blockchain-based gaming is by researching consensus techniques that are specifically designed for gaming environments. Moreover, since this reflection of blockchain-based gaming has been known for security vulnerabilities, especially those related to smart contracts, they could be tested against quantum computer attacks and designed to resist quantum computer threats as well. Moreover, scholars may propose robust blockchain architectures designed for gaming purposes that have a lower communication overhead with alternative distributed storages along with blockchain.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

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DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. The ethical issues; including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy has been completely observed by the authors.

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Biography



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