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Blockchain as a Learning Tool: Analyzing Transaction Speeds at Various Gas Limits in Computer Assembly Simulations

Yunifa Miftachul Arif[1]* Muhammad Khairul Amin Imron[1] Ajib Hanani[1]
Hani Nurhayati[1] Ahmad Fahmi Karami[1] Mokhamad Amin Hariyadi[1]

[1] *Department of Informatics Engineering, Universitas Islam Negeri Maulana Malik Ibrahim, Malang, Indonesia*
* Corresponding author's Email: yunif4@ti.uin-malang.ac.id

Abstract: The study explores an Ethereum blockchain-based data-sharing system for a computer assembly simulation game, emphasizing the relationship between gas limits and transaction speeds. The research integrates smart contracts for secure data storage of scores and player profiles. A significant challenge identified was the complexity of blockchain's variable transaction speeds for the average user. The research investigated how different gas limits affected transaction times, with experiments conducted across three networks. Results show that a gas limit of 200,000 to 300,000 resulted in transaction speeds of approximately 30 seconds. Increasing the gas limit to 400,000 to 500,000 reduced transaction times to 15-30 seconds, while a limit of 600,000 to 700,000 led to speeds below 15 seconds. These findings suggest a direct correlation between higher gas limits and quicker transaction validations. The research concludes that investing in higher gas can significantly reduce transaction times, presenting a trade-off between cost and speed in blockchain data-sharing for educational simulation media.

Keywords: Blockchain, data sharing, Transaction speed, Simulation game, Computer assembly, Ethereum, Smart contracts, Gas limit.

1. Introduction

Computer assembly simulation is a learning media in simulation games that allows players to learn how to select, install, and configure components in a computer. This simulation has a background related to the development of computer technology and the increasing public interest in the world of technology for education and training [1]. In the beginning, assembling computers was limited to people with a technological background and knowledge of computer hardware. However, as more information and guides become available on the internet, more and more people are now interested in building their computers.

The use of virtual reality (VR) in a simulation can provide a more immersive and realistic experience because users can experience the environment and interact with objects directly [2-4]. In general, VR is more often used in single-player games, especially for education, but in this research, VR will be applied in multiplayer games [5, 6]. In multiplayer VR games, players can communicate and interact in the same environment and share information [7]. This can provide a unique social experience and increase communication skills and the sensation of competition between players [8]. In the simulation of assembling a computer, VR can allow users to experience installing components on the motherboard, connecting cables, and installing the casing. With VR, users can see a 3D display of the components directly and experience the same sensations and movements as when installing the components on a real computer.

Games are one area that can be an object for utilizing the Ethereum Blockchain network, especially in multiplayer games [9-11]. In a multiplayer game, players often interact, such as sending messages, making transactions, or sharing data. The innovative contract feature on the Ethereum Blockchain will be very suitable for developing a data-sharing system in a multiplayer game [12, 13]. A data-sharing system in games will be needed because it can provide important information to players, such as information about the points or levels achieved by each player. This system will be challenging to implement and complex if it uses a database or cloud server in general which is centralized [14] because the privacy of player data can be threatened because the management and distribution of data is only known by the cloud and not by the user [15].

Meanwhile, the data distribution will differ if the game's data-sharing system is developed using the Ethereum Blockchain. This data will remain visible as long as the Ethereum Blockchain network exists. The data will be stored in an encrypted block, and everyone connected to the network can see and validate it [16]. In simple terms, each player and device will become their server and client because the Ethereum Blockchain network does not have a central server [17]. Therefore, the Ethereum Blockchain network was chosen for the data-sharing system for player points in the computer assembly Simulation game.

In the progress of the digital era, data sharing has become very important and necessary in various sectors, including games [18, 19]. In-game data-sharing systems will be needed because they can provide important information to players, such as information about points or level achievements. A points-sharing data system can positively impact each player because a competitive spirit will be formed so that players will compete with each other to get high points to compete with other players. In the conventional data-sharing process, there is usually an intermediary or third party who facilitates the process [20-22]. However, with intermediaries, transparency and accountability are sometimes less maintained. In research conducted at Cornell University by several researchers, it was found that intermediaries can increase data security risks. Therefore, technology is needed to increase security and transparency in data sharing. One technology that can increase security and transparency in the data-sharing process is blockchain [23, 24]. The data-sharing process using blockchain is one of the main recommendations because this technology provides an excellent security mechanism [25]. Every transaction carried out in the blockchain is recorded and verified automatically by the network [26, 27]. In blockchain, every transaction is protected by powerful encryption technology, so data will be complicated to manipulate and steal by unauthorized parties [28]. In the data-sharing process, a fundamental thing is vital, namely data security, especially personal data [29]. The data-sharing process using blockchain can also increase efficiency and speed because each transaction is sent directly to the network without having to go through intermediaries, so a process with high efficiency and speed is obtained [30]. Apart from that, data sharing using blockchain can also reduce the costs required.

This research introduces the novel application of Ethereum Blockchain technology within a multiplayer VR-based computer assembly simulation game, which presents a unique convergence of immersive learning and decentralized data management. Unlike traditional centralized systems, our method leverages smart contracts to facilitate real-time, secure, and transparent data-sharing among players without intermediaries. This feature inherently enhances data security and privacy, as each transaction is immutable and verifiable by all participants in the network, thus eliminating the security risks associated with third-party data management [18, 31]. Furthermore, integrating blockchain into VR gaming for education constitutes an innovative step towards interactive learning environments where users gain hands-on assembly experience and partake in a competitive yet collaborative ecosystem. This approach significantly surpasses existing educational simulations by offering a more realistic, engaging, and secure way of learning, which is instrumental in fostering technical skills in computer hardware assembly among a broader audience without specialized knowledge.

As we conclude this introductory section, we have outlined the backdrop against which our research unfolds, underscoring the intersection of technological evolution and educational methodologies. The forthcoming section, Related Work, delves into a critical analysis of preceding studies that align with our theme, highlighting the distinctions that set our research apart. After this, the Methods section will articulate the intricacies of our game flow design, multiplayer flow design, and data sharing flow design, laying out the systematic approach we adopted in creating the simulation. The results and Discussion section follows, presenting a comprehensive account of our findings, including gameplay and data sharing system visualization, blockchain connection testing, data sharing testing, transaction speed testing, and comparative analysis. Finally, the Conclusion section will encapsulate the essence of our research outcomes, reflecting on the implications and potential trajectories for future work in this domain.

2. Related work

The application of blockchain technology in gaming has emerged as a fascinating topic among researchers, particularly within learning and simulation. Various studies have delved into this aspect with differing focal points, all contributing to advancing blockchain-based educational technologies. In the context of cloud gaming, as elucidated in [32], blockchain technology is employed to rectify shortcomings in pricing models. CryptoArcade, for instance, offers a transparent and resource-based pricing method using cryptocurrency. This facet could be adapted for computer assembly simulations, where payments for virtual components and access to educational modules could be managed using tokens traded via smart contracts.

References [11] and [18] discuss using blockchain to support data sharing for game recommender systems. Both studies transmit the necessary data recommendation systems required to generate player suggestions. Furthermore, references [33] and [34] discuss the privacy and interoperability within blockchain technology. Reference [35] also discusses the privacy and security of score transactions in multiplayer games. In the context of computer assembly simulations, safeguarding user data privacy is crucial, and the solutions proposed in these references for securing energy trade data could inspire protective measures for user data within computer assembly simulations. Next, reference [36] highlights the opportunities and obstacles in adopting blockchain-based games. This research emphasizes the importance of identifying and overcoming technological, organizational, and environmental barriers for successful technology implementation. This is relevant to our study as it suggests that a similar approach could be applied in developing blockchain-based learning media for computer assembly.

Regarding learning and education, reference [37] highlights how big data technology and artificial intelligence can revolutionize the gaming and education industries. This research could inspire using big data and intelligent learning to tailor learning experiences within computer assembly simulations. Furthermore, reference [38] broadens this discussion by exploring how digital scarcity and blockchain-verified ownership create value in games. This scarcity principle could be adapted within an educational context to make computer assembly simulations more engaging and provide additional motivation for users. Finally, reference [39] presents the application of serious games in a crowdsensing context, focusing on urban water resource management. Although its focus is not on computer education, the concepts of serious games and crowdsensing could be adapted to create interactive and educational computer assembly simulations.

Although previous studies have addressed various aspects of blockchain use in gaming, several significant research gaps were identified. Blockchain has been explored in gaming, but its application in learning simulations, especially computer assembly simulations, still needs to be explored. Developing and testing effective blockchain integration models to support technical learning in computer assembly simulations is necessary. Additionally, further explanation is needed regarding how blockchain can be used to design pricing models in virtual educational environments. Our research has the potential to fill this gap by exploring how Ethereum can facilitate a functional data transaction system in the learning process of computer assembly simulations. Finally, few studies have extensively explored the creation, distribution, and verification of learning content for computer assembly using blockchain. Our research offers insights into developing unique, manipulation-resistant digital learning content that can guarantee the authenticity and accuracy of educational materials.

3. Methods

In this research, we build a data-sharing system between players using blockchain for a virtual reality-based computer assembly simulation game. Fig. 1 shows the framework of the proposed system, where several players are connected in a game with a data-sharing system using a blockchain network.

3.1 Game flow design

Computer assembly games are usually categorized as simulation or management games [40]. Computer assembly simulation games are educational games that simulate selecting and installing the components needed to assemble a computer [41, 42]. When playing, players will run the game flow as in Fig. 2 to get a visualization of data sharing. The game flow is divided into four parts, namely Menu, Blockchain Connection, Gameplay, and data sharing system. After visiting the main menu, a blockchain connection process will occur to play the game, and if successful, the player's token balance will be displayed. After completing the computer assembly simulation game, players will get points and enter multiplayer mode. In multiplayer mode, the data-sharing system is in place. Namely, the system will display information on data points, names, and token balances of each player connected in one room.

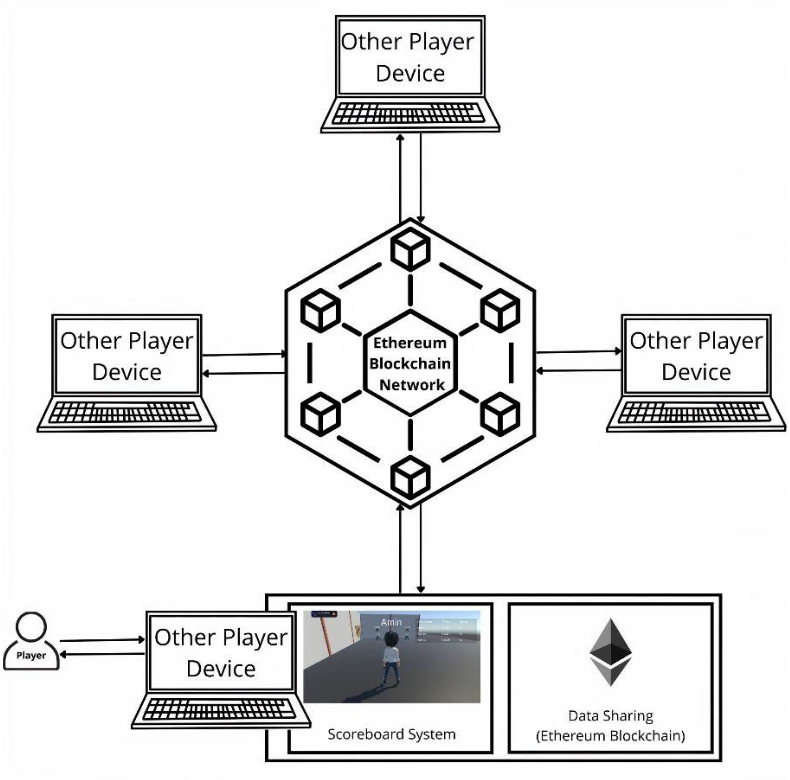

Figure. 1 Proposed system framework

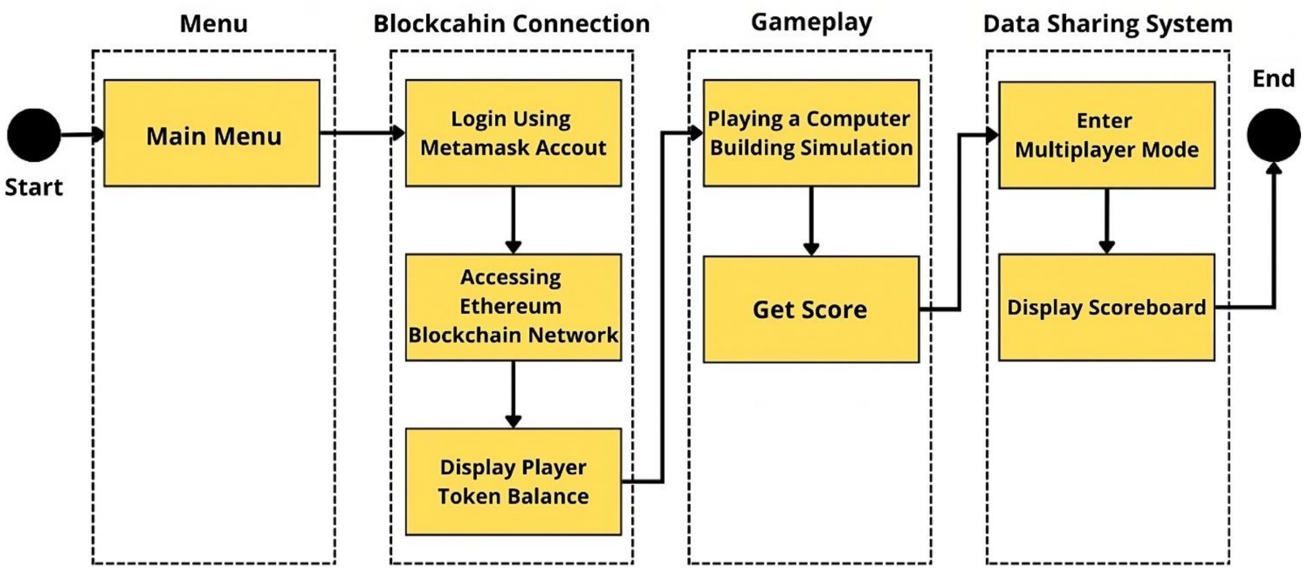

Figure. 2 Computer assembling simulation game flow

3.2 Multiplayer flow design

In multiplayer games, servers and clients exchange data by sending packets over the network [43]. To create a shared virtual space for players connected from different locations, events in the game process (such as character movement or object creation) are synchronized with other clients by sending data packets to them [44]. The transport layer is responsible for sending and receiving packets over the network.

In developing multiplayer games, every element in the game needs to be synchronized, including the local coordinate system, 3D objects, text, and animation [45]. To synchronize these elements' charges, researchers used Photon Unity Networking's basic settings [43]. The synchronization framework for these elements is visualized in Fig. 3. The figure illustrates how the various components of the shared

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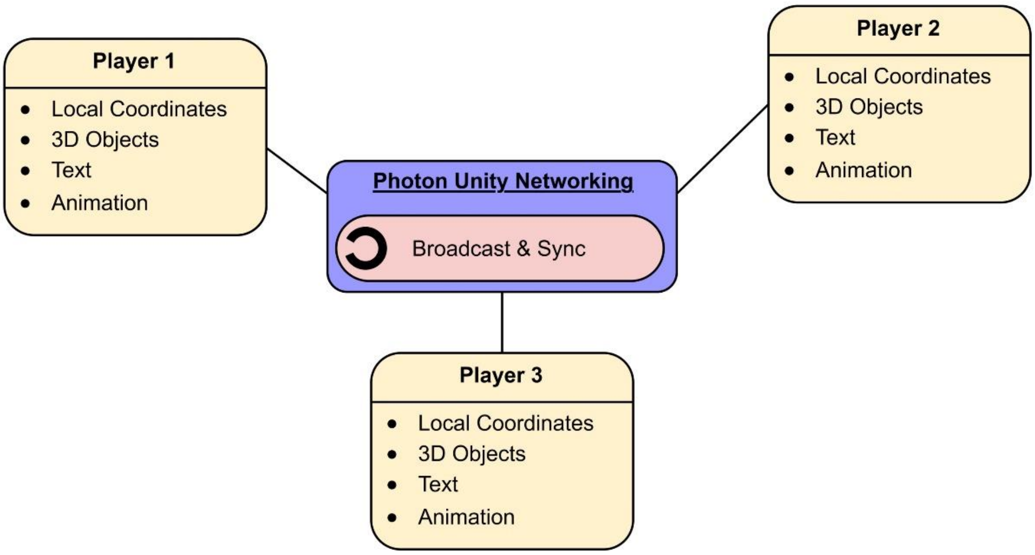

Figure. 3 Multiplayer data sync flow

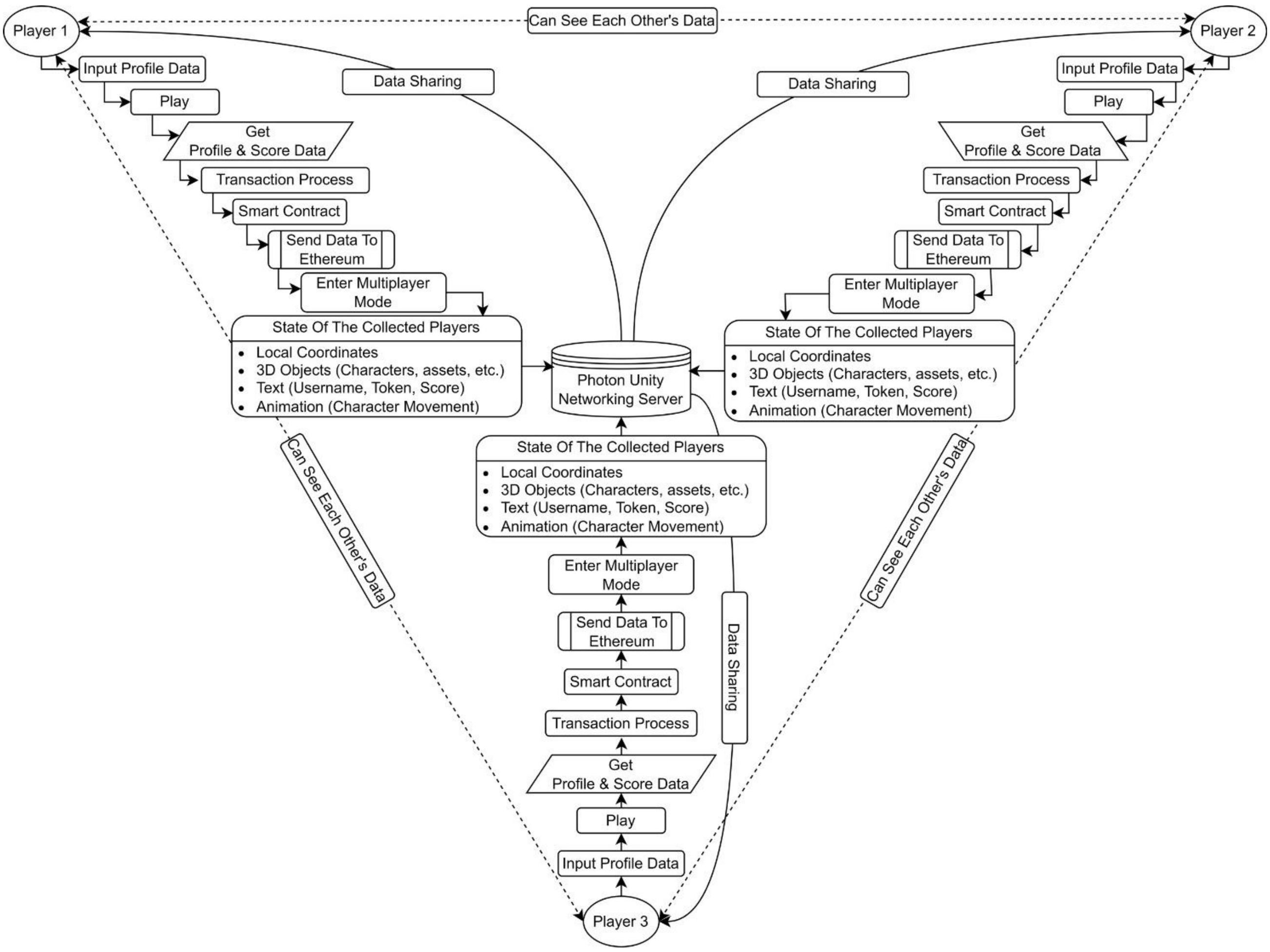

Figure. 4 Data sharing system flow

experience are synchronized across three users, using photon unity networking and RPC (remote procedure calls) that correlate the content state across the three users.

3.3 Data sharing flow design

The illustrated data-sharing flow plan depicted in Fig. 4 relates to the interactions within a computer assembly simulation game, highlighting participant data exchange. This exchange allows participants to interact within the game even in different physical locations, thus enabling a synchronous data-sharing setting. The diagram likely maps the sequence and conditions under which data is transferred, reflecting the collaborative aspect of the simulation that requires players to be co-located for optimal communication and strategy execution.

Initially, a player will input profile data when entering or logging into the game; that way, the player can play the game. After the game is completed, player profile and score data will be obtained and sent to the blockchain network by passing a predetermined smart contract. The profile and score data between players connected to the network can be sent and displayed.

Then, when the player enters multiplayer mode, several elements in the game will be called up, including the local coordinate system, 3D objects, text, and animation. As for profile and score data, they were previously included as text elements in the game. Next, the collection of data elements will be sent to the photon server, and then the photon server will be synchronized and broadcast back to each connected player.

4. Result and discussion

This chapter presents the outcomes of deploying a data-sharing system within a multiplayer computer assembly simulation game, highlighting the extensive testing conducted using the Ethereum blockchain platform. This encompassed connection, data-sharing, and transaction speed tests. Key variables affecting the tests included gas price, gas limit, and gas consumed—determined during trials with a MetaMask wallet account on the Mumbai test network. Ethereum's decentralized structure ensures each transaction's integrity and verifiability. Smart contracts automated and secured the data-sharing process, ensuring transparent, unalterable records—crucial for real-time data accuracy in simulation games. Our Mumbai test network trials validated the system's strength, optimizing transaction costs and preventing network misuse, thus enhancing an efficient and scalable gaming experience.

4.1 Gameplay and data sharing system visualization

In this research, we built a simulation game for assembling a computer with a 3D display. Fig. 5 shows what it looks like when playing a game created using the Unity engine. When playing the game, each player can see the score they have obtained via the information board. Fig. 6 displays the information board, which displays some of the player's data, such as name, token balance, and score.

Figure. 5 Gameplay visualization

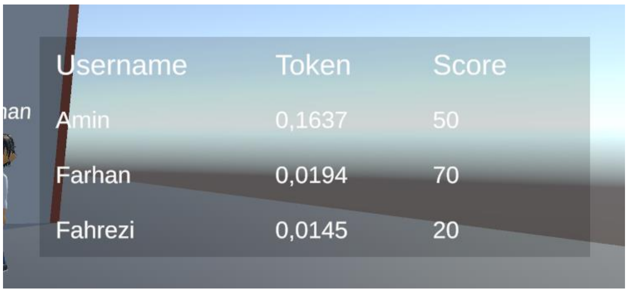

Figure. 6 Information board

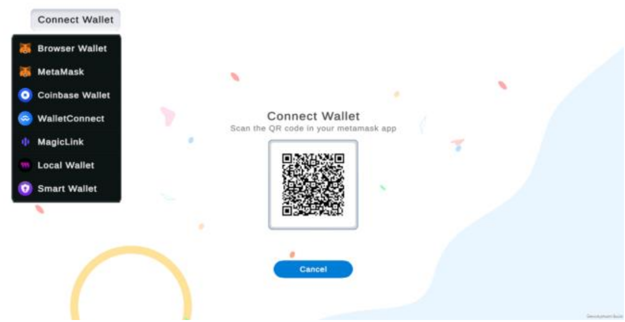

Figure. 7 Ethereum wallet connection

4.2 Blockchain connection testing

In this research, we built a simulation game for assembling a computer with a 3D display. Fig. 5 shows the user interface example of an Ethereum wallet connection.

As in Fig. 7, players can connect their blockchain account using the Metamask wallet by scanning via smartphone. If the Ethereum blockchain network connection is successful, the player's balance and wallet address will be displayed as in Fig. 8.

It can be seen in Fig. 9 that the trial of connecting the blockchain network with the system via three different devices and three different accounts shows high results in terms of success rate.

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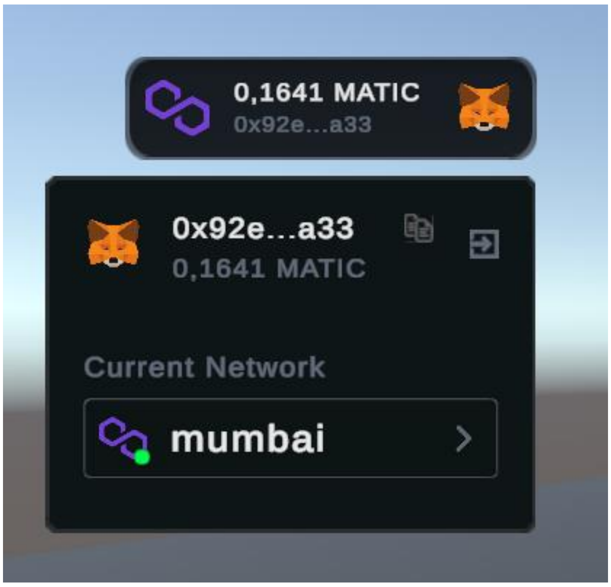

Figure. 8 Information Board

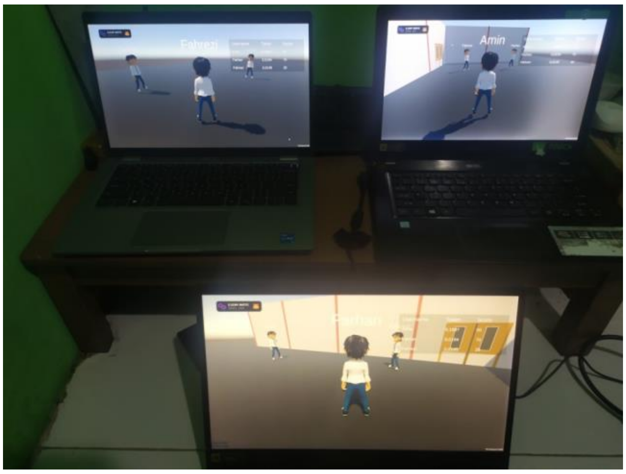

Figure. 9 Connection testing with three devices

Figure. 10 Data sharing testing

Table 1. Data sharing testing

Device	Nickname	Spawn	Display
1	Amin	Succeed	Appropriate
2	Farhan	Succeed	Appropriate
3	Fahrezi	Succeed	Appropriate

4.3 Data sharing testing

This test is carried out to determine whether each player's balance and score can be displayed appropriately and seen by other players. Information related to each player's remaining balance and score will be displayed as a scoreboard in the top right corner of the user interface. Each player in the room can activate the scoreboard by pressing the TAB key on the keyboard. Fig. 10 illustrates the player interface, which displays the balance and score owned by each player in one room.

The following is data from testing results with three devices and tests carried out with players entering the game. The "Spawn" column is considered successful if the player successfully enters the game arena. The "Display" column is deemed appropriate if data sharing of token balances, names, and scores is successful in the game.

Based on Table 1, the data-sharing test results for token balances and player scores were successfully implemented. All players successfully appear in the game, and the display of balances and scores between players corresponds to what they each have.

4.4 Transaction speed testing

This aims to evaluate the transaction confirmation speed by the blockchain checking site, namely https://mumbai.polygonscan.com/. Testing involves changing the value of a gas limit variable previously tested. Next, several transaction attempts are performed, and the time required to process each transaction is measured. The average time required to process a transaction can be calculated using the formula Eq. (1).

$$\bar{T} = \frac{1}{n} \sum_{i=1}^{n} Ti \quad (1)$$

Before testing each scenario, adjusting the gas settings when carrying out transactions is necessary. In the metamask notification, pressing the button, as in Fig. 11, will allow us to adjust the gas parameters directly.

In the test, trials were carried out 20 times with a gas limit range of 200.000 – 700.000; then, the test data was standardized with a score of 100. The results of the test are shown in Table 2 and Fig. 12.

After testing transaction speed based on three scenarios that have been designed, it shows a comparison of time based on the gas limits applied. It can be seen that by using a gas limit of 200.000 – 300.000, the resulting transaction speed is in the

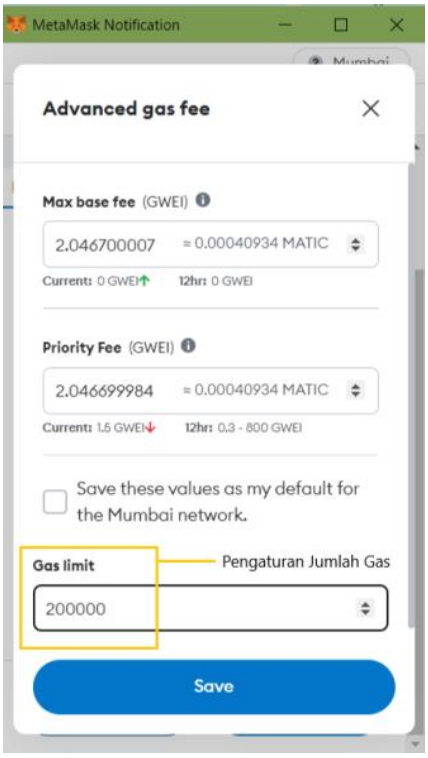

Figure. 11 Gas limit settings

Table 2. Transaction speed testing

Testing	Gas Limit					
	200 k	300 k	400 k	500 k	600 k	700 k
1	31	30	22	20	11	10
2	29	32	19	16	9	12
3	34	28	20	19	12	7
4	30	28	17	22	13	9
5	30	33	20	18	10	11
6	27	25	17	23	8	8
7	32	27	23	20	14	6
8	30	31	19	20	11	13
9	29	29	16	17	9	7
10	33	27	22	26	12	10
11	31	30	20	15	10	8
12	26	29	25	21	13	14
13	28	34	21	24	11	6
14	35	29	20	22	8	11
15	29	35	18	15	14	10
16	27	30	22	30	12	9
17	30	32	22	19	10	12
18	32	30	19	16	9	9
19	31	28	20	25	11	7
20	28	31	25	18	13	11
Average	30,1	29,9	20,3	20,3	11	9,5

range of 30 seconds, then by using a gas limit of 400.000 – 500.000, the resulting transaction speed is in the range of 30 - 15 seconds, while by using a gas limit of 600.000 – 700.000 the time obtained is under 15 seconds.

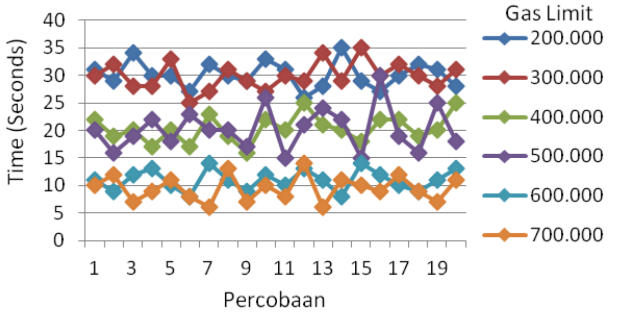

Figure. 12 Transaction speed comparison chart

4.5 Section comparison

This research produces a data-sharing system to overcome several forms of data distribution from users, systems and servers. This research has several different aspects compared to several implementations of blockchain data sharing in other research. Table 3 shows these differences one by one. Reference [18] explores the tourism sector, utilizing user preferences and ratings to enhance recommender systems. Although it leverages blockchain for data sharing, its scope is confined to recommender systems within tourism, focusing singularly on consumer preference data without the multifaceted data interaction seen in-game simulations. Reference [46] is in the manufacturing field and employs manufacturing data. Its blockchain application is rooted in non-game scenarios, primarily aiding cyber-physical systems. This differs significantly from our game-centric application, where the blockchain's role extends to encompassing a gaming environment's dynamic and interactive nature. Reference [47] uses blockchain to secure medical data sharing in the medical domain. Like [47], this is a non-game application, and while it deals with sensitive data, it does not address the complexities of data types and interactions present in gaming simulations.

References [11] and [35] engage more directly with the gaming industry; however, both studies limit their data usage to singular metrics—ratings for an RPG game and scores for an adventure game, respectively. They do not account for the multifarious data elements that our research considers. Our research, in contrast, integrates a broader spectrum of data types, including usernames, scores, and token balances, in a simulation game setting. This approach allows for a more comprehensive understanding of player behaviour and preferences, which is critical for enhancing the gaming experience through personalized content and recommendations. Our work signifies a step forward in applying blockchain

Table 3. Blockchain data sharing comparison

References	Field	Data Used	Difference
[18]	Tourism	Rating and user preference	Focuses on recommender systems
[46]	Manufacture	Manufacture data	non-game application
[47]	Medical	Medical data	non-game application
[11]	IAP in RPG Game	Rating	Only one data
[35]	Adventure Game	Score	Only one data
Ours	Simulation Game	Username, Score, and token balance	Involves more data

technology in the safekeeping and sharing data and utilizing a multifaceted dataset to enrich the user experience in computer assembly simulation games.

5. Conclusion

The results of the tests carried out 20 times with a gas limit range of 200.000 – 700.000 and a data score of 100 resulted in different transaction speeds. Meanwhile, by using a gas limit of 200.000 – 300.000, the resulting transaction speed is in the range of 30 seconds. Then, by using a gas limit of 400.000 – 500.000, the resulting transaction speed is 30 - 15 seconds, whereas by using a gas limit of 600.000 – 700,000, the resulting time is 30 - 15 seconds. under 15 seconds. Therefore, users can adjust the gas they want to pay according to their needs and priorities. Transaction processing will be faster by paying more gas, such as using a gas limit of 600.000 – 700.000.

On the other hand, users can pay less for gas, such as using a gas limit in the range of 200.000 – 300.000, with the consequence that they are likely to have to wait for a longer transaction validation process. The development of a data-sharing system in a virtual reality-based computer assembly simulation game utilizing Ethereum blockchain technology still has room for significant improvement. Several aspects require improvement to support future research and to improve the quality of the system and the game.

Conflicts of interest

The authors declare no conflict of interest.

Author contributions

Conceptualization, Y.M. Arif, and M.K.A. Imron; methodology, Y.M. Arif and H. Nurhayati; software, Y.M. Arif, and M.K.A. Imron; validation, Y.M. Arif, M.A. Hariyadi, and A. Hanani; formal analysis, Y.M. Arif, A. Hanani, and M.K.A. Imron; investigation, Y.M. Arif, M.A. Hariyadi, and A.F. Karami; resources, Y.M. Arif, and M.K.A. Imron; data curation, Y.M. Arif, A.F. Karami and H. Nurhayati; writing—original draft preparation, Y.M. Arif, and M.K.A. Imron; writing—review and editing, Y.M. Arif, A. Hanani, and M.K.A. Imron; visualization, Y.M. Arif, and M.K.A. Imron; project administration, Y.M. Arif, H. Nurhayati, and A.F. Karami.

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