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Serious Game for Blockchain Education Purposes (using Proof-of-Work consensus of Bitcoin)

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Abstract—**The blockchain-based system is widely being studied and implemented for dealing with various real problems from securing money transactions, data sharing in healthcare, and supply chain in businesses. In this study, we study a conceptual framework of a serious game for teaching how the mining process occurs in the blockchain using the proof-of-work consensus. The purpose of this game is to educate blockchain newcomers or developers the importance of mining within a short time, how the consensus works, the increasing problem complexity, and how coins can be obtained as the result of the mining. We believe that this conceptual game can contribute to the development of blockchain technology in general.**

Keywords—blockchain; education; mining; serious game

I. INTRODUCTION

Many researchers have developed blockchain-based systems in various sectors, e.g., securing bank payments [1], or assuring traceability in the food chain [2]. The reason being is because blockchain has advantages in providing tamper-proof and transparent information sharing. Instead of using a centralized third party for verifying the transaction data, multiple actors, in a distributed manner, participate in the verification process that is called mining. The quality of the shared information is assured through a comprehensive and rigorous verification process that follows a particular calculation and updating rules.

Commonly, many companies and organizations utilize serious games for workers' training purposes involving system explanations to users. For example, learning how to assign customers to restaurant tables [3], understanding the process of train rail maintenance and its difficulties [4], and teaching statistics [5]. In this study, we extend the applicability of serious games by proposing a game that can help beginners to understand how the mining works in the blockchain. Notably, we are talking about Bitcoin's proof-of-work consensus algorithm. The goal of our study is to attract more people's attention to the blockchain system, which, in turn, will foster a better understanding and development of blockchain for users and developers. The rest of this paper is described as follows. Sections II and III provide some basic concepts of the blockchain and serious games. Section IV lists some related studies in the blockchain game. Section V explains the architecture of proposed serious games, including actors and required data transfers within the game. Section VI shows the conclusion of the study.

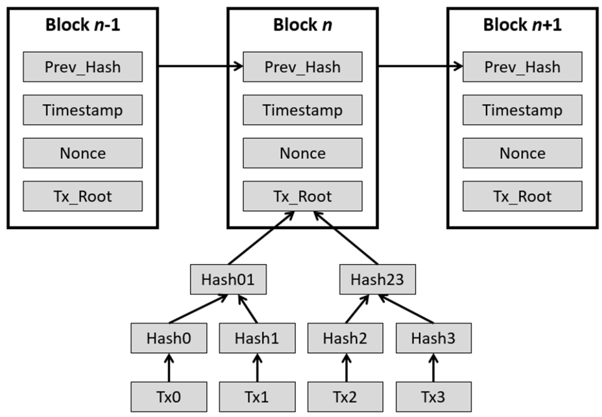

Fig. 1. Block structure in blockchain

II. BLOCKCHAIN

Blockchain is a peer-to-peer distributed ledger that shares information among all participants in its network [6]. A participant creates a transaction, and then broadcast it to other peers. The receiving peers may gather multiple transactions from many users and form a block. We can identify a block by its hash. Furthermore, It has a corresponding hash of the previous block that refers to the monetary state before the current block. The next block will also reference the hash of the current block, thereby creating a chain, as illustrated in [7] using Fig. 1. Each block comprises of two parts: block's

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header and block's body. We store a list of the transactions are in the body. Meanwhile, we save the metadata in the header. Finally, the node who construct the block broadcast the block to other peers.

Since any node in the network can send transactions to the other nodes and generate blocks arbitrarily. There will be many generated blocks scattered in the network. Therefore, there must be a method to make all of the participants agree on the same block. In other words, the participants have to achieve a consensus on how the distributed ledger looks like [8]. In Bitcoin, they use an algorithm called 'Proof of Work.'

In Proof of Work, all participants have to race to find a valid hash for the subsequent block. First, a participant gathers transactions into a single block and puts this transaction data in the block body. After that, he constructs the block header, which includes a timestamp, hash of the Merkle root tree from the transactions, the hash of the previous block, and a nonce [9]. He then hashes all of that information using the SHA-256 algorithm [10]. The resulting hash needs to match the difficulty target [6]. If the target is not satisfied, he can try changing the value of the nonce repeatedly until the resulting hash is satisfied [11, 12]. When he finds the correct hash, he broadcast the block with a valid hash to other participants.

When one participant receives broadcasted block from other participants, he verifies whether the block contains a valid hash. If the hash is legit, he extends his current block with the one he just received, and continue racing to generate a hash for the next blocks.

Bitcoin compensates a node which generates a valid block with coin rewards from the system [13], and also from the included transactions fee in the block he made [10]. This reward mechanism encourages other participants to continue racing to find the valid hash for the subsequent block. The way we find the valid block is analogous to the way we find gold in the mining field. Therefore, people sometimes refer to this process as mining and the participants who work to find a valid hash as miners.

During Bitcoin operation, a node may receive two valid blocks, and they have the option to extend the current block with both of them. Thus, it creates a fork, where there are two versions of the ledger in the network. Honest nodes can unintentionally create this fork, for example, if two nodes find a valid block at the same. However, this is rare to happen. What most likely to happen is that a malicious node (with very high computing capability) intentionally creates a fork to perform the Double Spending attack. Bitcoin solves this fork problem by a 'Longest Chain Policy,' in which nodes have to pick a block with the most extended block number when they receive multiple blocks at the same time [14].

Ironically, the only way to find the correct hash is by brute-forcing (i.e., try one combination after another for all possible outcome). Therefore, the miners need considerable computational power to do so [10]. The Bitcoin software always guarantees that any node can find this hash within approximately 10 minutes. This delay is necessary to assure that any broadcasted transactions can arrive at any node throughout the world, where the latency can vary across the globe. However, if more players join the network, participants can find a valid block in less than 10 minutes. In result, the network has higher chances of getting forks and inconsistency among nodes. Therefore, Bitcoin has a difficulty target that the developer can increase or decrease to maintain the stability of the network [15].

III. Serious Games

Serious games are defined in [16] as "*games that do not have entertainment, enjoyment or fun as their primary purpose*". Serious games can be used for the following purposes: training, advertising, simulation, and education [17]. Through the interaction with the game, the users are encouraged to think and make decisions that are useful for providing a wide variety of learning values. Some examples of serious games are freight transport mode selection [18], hostage saving game [19], and yard crane scheduling game [20].

The following characteristics need to be listed when designing a serious game:

- Market of the game, e.g., military, healthcare, education, politics, advertising, etc [16].
- Target of game, that can be differentiated into general public (anyone), professional (workers from the targeted market), and students [16].
- Purpose of game, e.g., informing basic types of rail maintenance and making users aware of difficulties in regular maintenance in a rail maintenance game [4].
- Dataflow and activity considered in the studied problem [21].
- Scenarios in the game that represents the increased difficulty in the considered problems.

Chamberlin [22] listed some recommendations for developing games with learning purposes as follows:

- The game should provide feedback for the users as they advance through the game. Scores and rewards can motivate users to play better.
- The level of user's involvement and decision making must be increased during the game.
- Challenges are required through an increase in game complexity and problems to be solved, but not exceeding the user capabilities.
- The educational information needs to be repeated in various places with different approaches.
- The users need to be involved during game development through discussions and regular game testing.

IV. Literature Review

Search for related studies about blockchain game is initially conducted from some databases with search keywords presented in Table I.

TABLE I. FIELDS AND KEYWORDS FOR SEARCH

Database	*Searched fields*	*Keywords for search*	*Number of found papers*	*Number of selected papers*
Web of Science [23]	Title	blockchain AND game	9	1
Springer [24]	Title		0	0
ScienceDirect [25]	Title, abstract, keywords		11	0

Most papers discuss strategies used during the mining process (e.g., negotiation game and game theory concepts in blockchain). Among all found papers, the only study about blockchain gaming is [26]. In [26], blockchain is used to track and verify players' assets and prevents cheats in a multi-player game.

In addition to those studies, more searches are conducted. The closest studies with ours are The Blockchain Game [27,28], The Cryptocurrency Board Game [29], and Rhythm Dungeon [30]. Christianson [27,28] proposed a classroom game activity for teaching blockchain to students. In the game, a case for storing students' scores is considered. Players act as miners to verify students' grade information. A hash number is calculated using the value of the first letter in the course ID, a public key assigned to the student, the grade, a part of the previous hash number, and a nonce that is represented by values between 1 and 3. The hash number is valid if it can be divided by 3 [31], and its value is checked by all other players in the game. Our study differs with [27,28] in terms of the complexity of the hash number generation, consideration of real transaction data, and computer-based data visualization to speed up to process of understanding the blockchain by the players. In The Cryptocurrency Board Game [29], players compete by buying and upgrading machines to perform mining process and gather the most amount of Bitcoins. The main purpose of the developed board game is creating values using money that exists in the cryptocurrency market and investing back the obtained money into the cryptomarket [32]. In Rhythm Dungeon [30], players use game characters to fight enemies by pressing buttons following given drum beats. The enemies are generated from other games using a smart contract. Defeating enemies allow players to improve their character skills. After playing in this decentralized blockchain environment, players can upload their characters to let them appear in other players' games. Our study is different with [29] and [30] because our game focuses on providing education about mining processes in blockchain (reading and verifying transaction data, updating blockchain node network, and collecting rewards) for the players.

Other different concepts of blockchain game are using blockchain's tokens for buying and selling processes when playing the games (the tokens are stored in players' e-wallet) [33] (e.g., CryptoKitties [34], Bitpet [35]), using smart contract for removing middleman during the payment process (e.g., EOSlots [36]), using blockchain to verify the authenticity of exchanged goods in the game (e.g., Gods Unchained [37]), players' identity management [38], and teaching blockchain concepts through fun quizzes with simple adventurous story game (e.g., CryptoZombies Origins: What is Blockchain? [39]). Review of more games is provided in [40].

Based on the authors' knowledge, our study is the first that propose an educational game for learning mining process in blockchain. Our proposed game provides detailed information related to data that must be validated, updated blockchain node network, and reward collection reports to support an exciting and competitive learning process of the players.

V. BLOCKCHAIN MINING GAME

We propose a conceptual framework for developing a blockchain mining game. The purposes of the game are:

- Provide education about how a blockchain system works, including how to perform the mining process, how consensus is achieved, and how the users collect the rewards.
- Encourage users to conduct further studies about blockchain.

The target users of the game are general public (including professionals and students). Professionals (e.g., software developers) that has no much background about blockchain but somehow want to develop new blockchain-related businesses can learn about blockchain through the game and develop useful blockchain software for solving real problems. Meanwhile, students from computer engineering, financial, and industrial engineering related fields can learn about blockchain basics that are useful when they act as users of blockchain systems or learn about how to develop a part of the blockchain system (e.g., user interface, hashing functions, data management, simulation, etc.). Our proposed framework is shown in Fig. 2.

The framework is divided into two parts, the main framework, in which the blockchain mining activities are performed, and game condition-based updating framework that is a supporting part of the main framework. The updating framework is used to ensure that required input data are stored and updated and allow the game to maintain its attractiveness (e.g., by designing game problems that match the user's capability). The detailed explanation for each part is presented below.

A. Game Condition-based Updating Framework

This part manages the user information and other blockchain system-related information. The game condition-based updating framework is as follows:

1) U1. Storing and updating user information: A user must register and log in before playing the game. A unique user ID is provided and used to identify the user throughout the whole game (U1.1). Starting from when a user registers into the game, a reward score accumulating process begins (U1.2). This reward score tracking is used to evaluate the user's performance in the game. An updated reward list is continuously presented for all users throughout the game to motivate users making better decisions by winning more

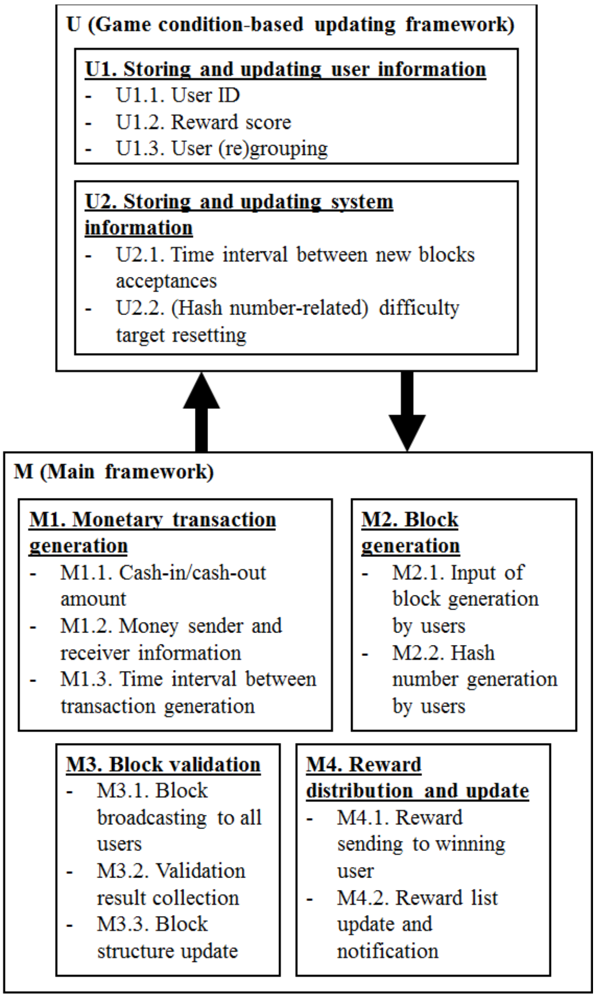

Fig. 2. Blockchain mining game framework

rewards. For assuring that users with similar computation capabilities compete with each other, the users are grouped based on their total collected rewards (U1.3) after playing the game for a certain amount of time (when one session of the game, e.g., 30 minutes, is completed, all transaction data and ledgers are reset, and another new fresh game is started). The reward list is generated for each user group. After a certain predetermined time, the groups are updated. The user with an updated group (moving to a higher or lower group) are notified, and the user information in the reward list of the new group is presented to the user.

2) U2. Storing and updating system information: The system stores how often a new block is validated and added into the common or distributed ledger (U2.1). In the real situation, it is expected that a new block is added every 10 minutes (t), which might be too long for our game. Thus, a shorter time might be set, e.g., 1 minute. A difficulty target is updated (U2.2) after a certain time period, e.g., 10 minutes, to assure that the time interval between a new block addition is as close as possible with the time t. If a new block is generated to fast, the difficulty target is increased, and vice versa.

B. *Main Framework*

The main framework consists of 4 parts:

1) M1. Monetary transaction generation: Users in this game deal with money transfer information between given n persons in the game. A transaction must have the amount and sender-receiver information (M1.1 and M1.2). Each transaction is generated randomly during the game with a given interarrival time between the generation of transactions. The system keeps track of each person's balance account and generates a feasible amount of money to be transferred, considering the updated balances. Each new transaction is added into a table in each user's monitor right after the transaction is generated.

2) M2. Block generation: Each user can access the information and determine which transaction he/she want to include into a new block. A block can consist of up to 5 transactions. This flexibility is to allow users generating more hash numbers, considering that the hash numbers are generated based on the contents of the generated block. A user can include the transaction into the block by dragging each specific transaction into a block shown in the monitor (M2.1). After the user confirms the block contents, the user must click a "generating hash number" button for generating a new hash number (M2.2). If the generated number is is less than the difficulty target that is generated by the system, the user is notified that a feasible hash number is found, the block generation is completed, and the user can continue generating other new blocks. An online hash number generator can be used for generating the numbers [41] after the game automatically copies the following values into the generator link: transaction contents, nonce, and timestamp. The timestamp itself is updated during the game continuously, e.g., in every 1 second.

3) M3. Block validation: A newly generated block is broadcasted to all users (M3.1). The information is added into a "new unvalidated blocks" list, and a notification is given to the users to allow them to determine whether to start validating the new block or continue mining another new block. If the validating user is already or currently generating another new block that contains partially or fully same transactions with the new one, the validating user is notified to encourage him/her to validate this new block first. The users then validate the new block (M3.2). If more than a certain number of users validate a new block, e.g., 51% of the users, then the block is validated. The validated block is used to update the block structure in the system (M3.3). The validated block and new block structure are then shared to all users. If the block contains any same transactions with the one that is being dealt with any other user, that user is notified and his/her not yet generated or validated block is removed automatically.

4) M4. Reward distribution and update: A user that generates the validated block is given a reward, e.g., 1.25 coins, every time his/her block is validated (M4.1). At the same time, the reward list in the corresponding user group is updated, and the information is shared to all users (M4.2). The users can then evaluate their performance compared with all other users and determine his/her next strategy for generating new blocks, e.g., selecting which transaction to be dealt with first.

TABLE II. THE DIFFICULTY LEVEL OF THE GAME

Difficulty Level	**Considered Functions**	
	Automatic update of user's own distributed ledger when a new block is validated	***Must validate a new block when a new block is generated (cannot continue generating other new blocks before completing the validation)***
Easy	Yes	Yes
Medium	No	Yes
Hard	No	No

C. *Evaluation Report and Game Level Update*

At the end of a game session, each user is provided with information of his/her performance, especially their total amount of collected reward and their placement in the reward scoreboard. Additional information can be provided in the evaluation report, e.g., number of own generated blocks, number of own validated blocks, average block generation time, etc, that are measured in relative with other users' performances. Beside automatically regroup users with similar reward scores, the user can always select whether to change the game difficulty. Considered levels of game difficulties and their characteristics are shown in Table II.

D. *User Interface of the Game*

We propose the following user interfaces (in Figs. 3-9). The user interfaces are developed based on the framework in Fig. 2.

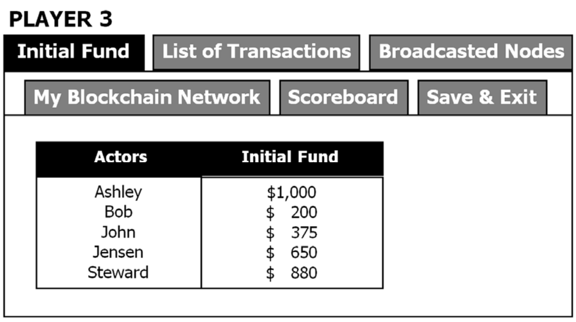

Fig. 3. User interface (actors' initial fund)

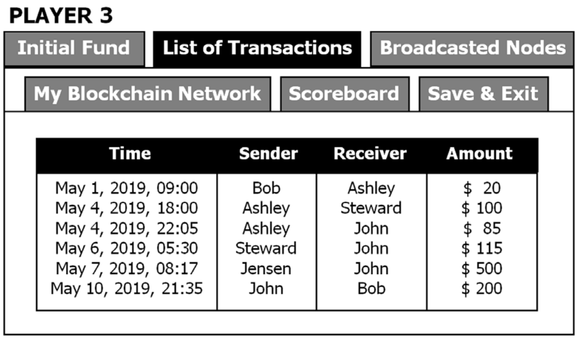

Fig. 4. User interface (list of transactions)

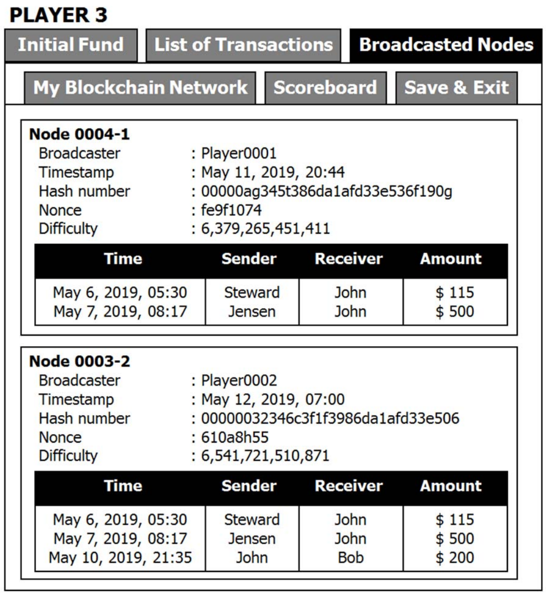

Fig. 5. User interface (broadcasted nodes)

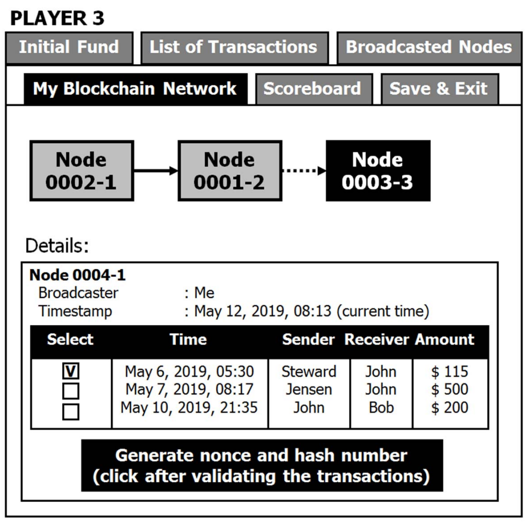

Fig. 6. User interface (player's blockchain network before hash number generation)

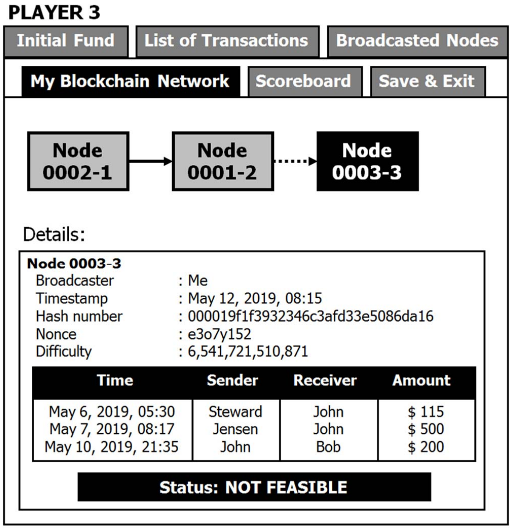

Fig. 7. User interface (player's blockchain network after infeasible hash number generation)

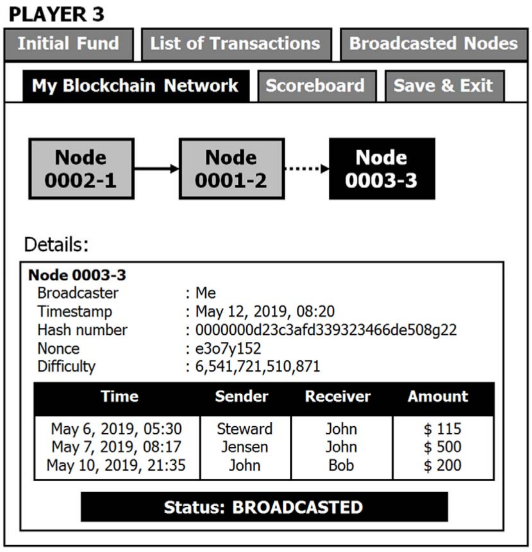

Fig. 8. User interface (player's blockchain network after feasible hash number generation and broadcasting)

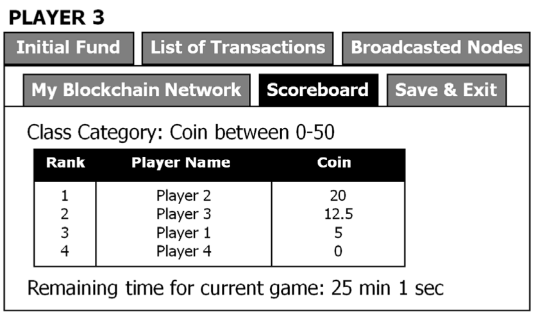

Fig. 9. User interface (scoreboard)

VI. Conclusions

In this study, a serious game for learning the blockchain mining process is proposed. A game story is designed with required mining-related activities. In the proposed game, the user's excitement is assured by allowing users to compete with other users that have the same level of skills. A performance evaluation report is evaluated at the end of the game to allow and relative performance result is also shown in real time to motivate users finding better ways to mine the blocks.

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