A New Approach to Mining Work in Blockchain Technologies

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ABSTRACT

In virtual currency using the blockchain technology that has drawn significant attention in recent years, the mining work concentration problem, whereby machine power is monopolized when supporting its operation, is becoming a serious problem. In particular, with the use of blockchain technology in future advanced mobile computing environments, the problem becomes more serious.

In this paper, to solve the problem, we developed a simple virtual currency service that allows a user to operate the service by giving the user a new incentive based on gamification, not traditional economic incentives. We conducted experiments that show the feasibility of adopting the alternative incentive. The experiments also allowed us to extract some insights regarding the use of blockchain technology in future advanced mobile computing environments as an essential building block for developing future digital services.

CCS Concepts

• **Computing methodology** → Distributed computing methodology Interaction paradigms

Keywords

Mining Work Centralization; Gamification; Cryptcurrency; Human Crowd's Power;

1 INTRODUCTION

In recent years, blockchain technology, which prevents duplicate trading and tampering of data, has drawn a significant amount of attention due to its ability to make our society more robust and efficient. Blockchain technology is actually a part of a virtual currency (encryption currency) system named Bitcoin proposed in 2008; the technology makes it possible to carry out reliable commercial transactions that do not go through third parties on the Internet, which was difficult to realize before [12]. The blockchain technology not only issues its own currency [16]; it has also been used for domain name service [13], smart contracts [11], etc. The possibility of being used for various services in advanced mobile computing environments will be increased in the near future, and the blockchain technology will become an important infrastructure to support various services in the advanced mobile computing environments.

While the blockchain technology is expected to be a next-generation technology, some problems have also been pointed out. Since the operation of the Bitcoin network system is carried out by distributing the machine power through P2P communication, it is possible to be able to selfishly manipulate transaction data by monopolizing more than 51% of the total machine power. Taking Bitcoin as an example, incentives for the Bitcoin operation are to earn its virtual currency. Because only economic incentives are used to obtain the currency, some users aim at obtaining the currency by preparing a huge amount of machine power, and the machine power has been centralized [7]. Such a problem is referred to as the mining work concentration problem.

In advanced mobile computing environments, it is necessary to gather machine power from every computer to obtain truly decentralized agreement that is essential to realize decentralized trust, so incentives to provide machine power from distributed users are necessary. When using the blockchain technology in advanced mobile computing environments, the mining work concentration problem that hinders the distributed agreement becomes a serious problem because in various real world services in advanced mobile computing environments, distributed trust is essential; however, typical advanced mobile computing devices may not be powerful enough for mining work. Thus, the centralized machine power tends to monopolize more mining work.

Many techniques have been studied to solve the mining work concentration problem by suggesting a new mining algorithm, but no research has given a new incentive to the user. In this study, therefore, by using a method called gamification to motivate people through psychological factors [8], we investigated whether the mining work concentration problem can be solved by providing incentives based on psychological factors through gamification rather than offering economic incentives.

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The remainder of this paper is organized as follows: Section 2 introduces the existing studies on the mining work concentration problem in Bitcoin and the existing studies on gamification concerning human motivation. In Section 3, we will discuss our approach to gamification to solve the mining work centralization problem. In Section 4, we describe the experiments to justify the feasibility of the proposed approach, and Section 5 describes the results obtained from the experiments and presents some useful insights from the results. Section 6 concludes the paper and presents future issues in this research.

The contribution of this research suggests the possibility of solving the mining work centralization problem without using economic incentives by proposing an alternative approach using gamification. The proposed approach promises to adopt the blockchain technology in advanced mobile computing environments; the decentralized power of human crowds offered through gamification prevents the monopolization of mining work through powerful machine power.

2 RELATED WORK

2.1 Bitcoin Mining

The most notable blockchain technology is the virtual currency named Bitcoin, invented in the paper written by Nakamoto in 2008 [12]. He claimed "*To implement a distributed blockchain server on a peer-to-peer basis, we will need to use a proof-of-work system similar to Adam Back's Hashcash*". Hashcash refers to data and nonce, and it is a mechanism that does not allow transactions to be approved until the hash value becomes less than a certain value [2]. By making hassle-free calculation to confirm the transaction using the hash value, it requires huge machine power for preventing illegal transactions.

The mechanism that requires machine power for the approval of a transaction is called Proof-of-Work (PoW). In order for Bitcoin to operate stably, a large number of users need to perform PoW in their computers, so incentives for the users to provide the machine power are required. Nakamoto also said in his paper "*By convention, the first transaction in a block is a special transaction that starts a new coin owned by the creator of the block. This adds an incentive for nodes to support the network, and provides a way to initially distribute coins into circulation, since there is no central authority to issue them*" [12] Such a mechanism that obtains Bitcoin as a reward using the machine power is represented as mining by analogy to digging out gold at a mine.

2.2 Mining Work Centralization Problem

When the machine power concentrates on one entity, it is pointed out that the entity can modify the chain, which makes it impossible to maintain the legitimacy of the system. For example, as presented in [5], the authors claimed "*Too much hash power controlled by one entity can cause Bitcoin to become similar to the payment systems and currencies it was meant to improve upon. A pool with more than 51% of the network hash power can block transactions, double spend, and change other consensus rules.*"

As shown in [6], the authors claimed "*By using the latency of the network such as deliberately shifting the disclosure timing of block information, we can create a situation where block generation can be monopolized without holding 51% of machine power*". In [11], the author indicated that the Bitcoin mining algorithm has vulnerability to a single concentration and is no longer dispersed; then he proposed solving the problem where it creates random data based on the state of the blockchain, computes randomly chosen transactions from the last N blocks of the blockchain, and returns the resulting hash.

Proof-of-Stake (PoS), an alternative to PoW, has also been proposed, and King and Nadal also reported PPCoin: the first virtual currency based on PoS [9].

2.3 UbiPay

UbiPay [17] is a mobile payment scheme that drives transaction cost toward zero by offering a range of user modes and applying a minimum fee based on the situation. Their goal is to make paying as easy as breathing.

UbiPay is an important scheme to discuss a digital payment system used cryptocurrency technologies. In [17], the authors aimed to zero cost transactions and situation-based minimum fee. This concept is suitable for the cryptocurrency base payment system. Bitcoin and most of Bitcoin-based cryptocurrency systems can send small price transaction. This price is smaller than legal currency minimum units. In a Bitcoin network, the minimum transaction value is approximately 0.0006 cents in the protocol level. Cryptocurrency has an easy payment way and low transaction costs compared with the legal currency. We think that these features are essential to realize UbiPay.

2.4 Gamification

Digital designers have recently begun adopting ideas from game design to incentivize desirable user behaviors. This approach is known as serious gaming in education, and it is sometimes referred to as games with a purpose in human computing [1]; in [10, 15], the authors discuss designing incentives to increase participants' activities. Most recently, in [8], the authors defined gamification as follows: "*Gamification is a process of strengthening services with gaming experiences to support users' activities.*" In particular, gamification has already been adopted in various social media to facilitate users' social activities on social media.

FoldIt, a protein structure prediction game developed by David Baker, can be frequently cited as a research example that could solve the protein structure prediction problem by using gamification. With FoldIt, the problem has been made into games and played by users, not machines; the structure of AIDS-related proteins, unknown for over 10 years, was solved with Foldit [4].

As shown in Section 2.2, the automated mining approaches may cause the mining centralization problem. However, the gamification-based approach like [14] offers a possibility to decentralize the mining through crowds of people; then the

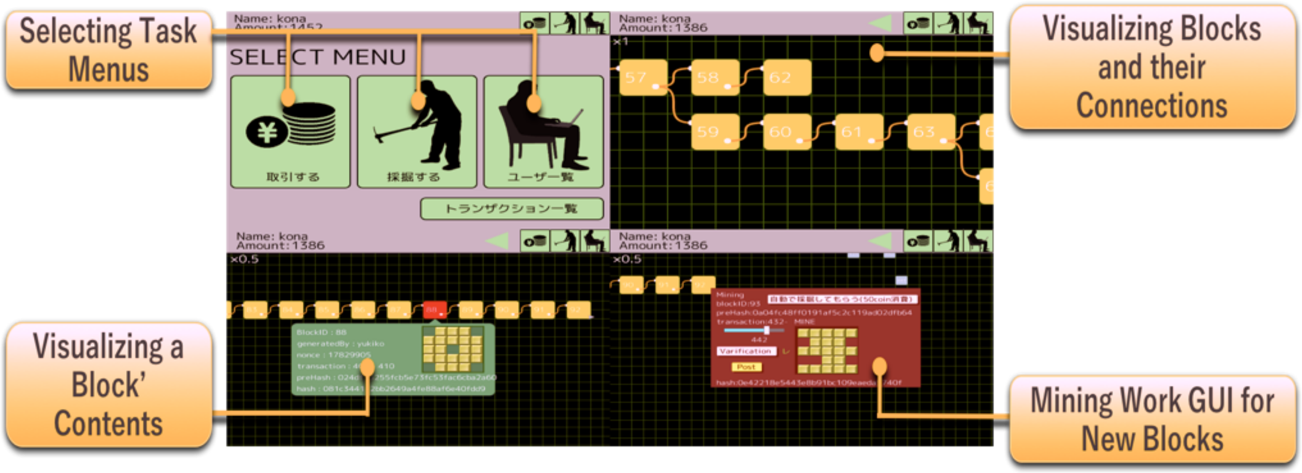

Figure. 1. A GUI Screenshot of the Proposed Service

approach is more appropriate for realizing the basic fundamental idea, decentralized operations of the blockchain technologies.

3 OUR APPROACH

3.1 An Overview of Our Approach

We design a gamified service to justify our approach and focus on the mining work centralization problem. It is a customized and simplified virtual currency system based on the blockchain technology developed for justifying this research, giving incentives based on psychological factors using gamification against mining work and allowing users to perform approval work. Our current system is to extract the functions related to the mining work for making the validation of our approach easy. The current focus of this study is to validate the feasibility of our gamification based approach on the mining work centralization problem, and the approach can be implemented in traditional P2P blockchain implementations without great efforts. Thus, our approach does not affect the reliability and security of the original blockchain approaches.

TABLE 1. ACCOUNT FIELD

Elements in Account	
USERNAME:	a user name
PASSHASH:	a hashed password
AMOUNT:	the amount of coins

The developed service consists of the following elements.

Currency Unit: In this service, the unit of virtual currency used is expressed by [coin].

Communication protocol: For the sake of simplicity, the client/server model was used for developing the service. Although the blockchain technology is typically used in the P2P method, since the purpose of this experiment is only to give incentives for psychological factors to mining work, adopting the client/server method would not affect the results.

Account: The service needs to create an account for each participating user. The account is provided with the fields shown in Table 1. In order to mine virtual currency, it is necessary to generate a block. Also, for generating a block, it is necessary to generate a transaction.

TABLE 2. TRANSACTION FIELD

Elements in Transaction	
TRANSACTIONID:	transaction number
GENERATEDBY:	transaction publisher
DEST:	destination name
INPUTS:	the amount of payment
OUTPUTS:	the amount of remittance
CHARGE:	the amount of fee

TABLE 3. BLOCK FIELD

Elements in Block	
BLOCKID:	block number
PREHASH:	previous hash
NONCE:	the amount of coins
GENERATEDBY:	block publisher
TRFROM:	contained first transaction number
TRTO:	contained last transaction number
HASH:	block hash

Transaction: The service exchanges virtual currency between users. For sending coins to others, the remittance account name and the amount of coins can be registered. In the transaction data, the fields shown in Table 2 are provided. When the transaction is performed normally, the transaction data is added to the

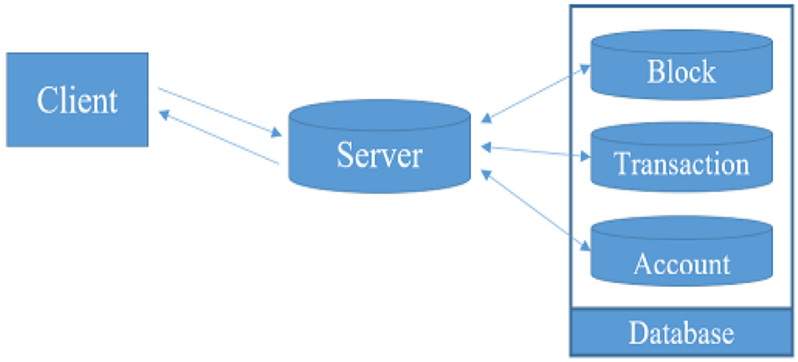

Figure 2. System Configuration

transaction data list, and the user can confirm the contents of the transaction added to the data list at any time.

Block: The service generates blocks storing multiple transaction. The creation of the block is done in the visualized state by a user. The field indicated by Table 3 is provided in the block. The user stores the hash value of one block in the newly generated block. Blocks can be connected like unidirectional chains. When the approval work succeeds by the mining work to be described later, the block is added to the block data list. Block information and blocks are added to the preceding and succeeding blocks, and the service can check how it is connected in a visualized state.

Mining Work: In order for a user to generate blocks and to add them to the block list, the block approval work is required. When blocks are approved and the chain extends from the block for the longest time, the block creator is given a reward. The mining work in this service is performed by manipulating visualized values by a user. In the game design, the value of the nonce in the block is made to correspond to the shape of the puzzle on the 5 × 5 board surface. The purpose is to make the user voluntarily perform a series of tasks of changing the value of nonce and performing approval work.

3.2 Service Design

In this service, a server/client model is adopted as shown above. The server mainly deals with data; account, transaction, and block. In a client, the service to offer the functions necessary for mining work and exchange of virtual currency is provided to a user. All operations by the user are performed through a Graphic User Interface (GUI) and provide six modes according to the necessary functions. The explanation of each mode is listed below, and the execution screen of the application is shown in Figure 1. Also, a configuration of the server used in this experiment is shown in Figure 2.

Account Registration and Login: The service registers a new account or logs in with an existing account.

Menu: It is possible to change to the transaction generation mode, the account list confirmation mode, the mining mode, (automatic or manual) and the transaction list confirmation mode, respectively.

Transaction Publication: The service can create a transaction for coin remittance from the account the current user is using, for any existing account.

List Up Account: The service can check the list of account names in the registered account list.

List Up Transaction: The service can check the list of transaction lists.

Mining Work: The service allows a user to check the list of block lists visually. The blocks are connected by hash value. It can generate a new block from the existing latest block. In order to generate a new block, mining work is necessary, and let this user do this work on the GUI.

4 EXPERIMENT METHOD

In order to evaluate whether the developed service gives users enough incentives for psychological factors caused by gamification, we run the service and conduct experiments using a questionnaire based on users' answers.

4.1 Overview

This experiment was carried out by distributing client software for a total of 44 people (Age: 10-20) offering the service described in Section III. The experiment period is one week. The evaluation was carried out using the statistical data obtained after the experiment and the questionnaire result of the optional answer.

In addition to manually performing mining work to evaluate whether mining work was done as a result of incentives for psychological motivation, the function of automatically mining work with a certain probability by consuming coins held. This approach imitates the mining work in conventional Bitcoin whereby the problem is solved using machine power. If there are users who manually perform mining work even under this circumstance, within the game, it can be said that the incentive of the psychological factor through gamification is meaningful.

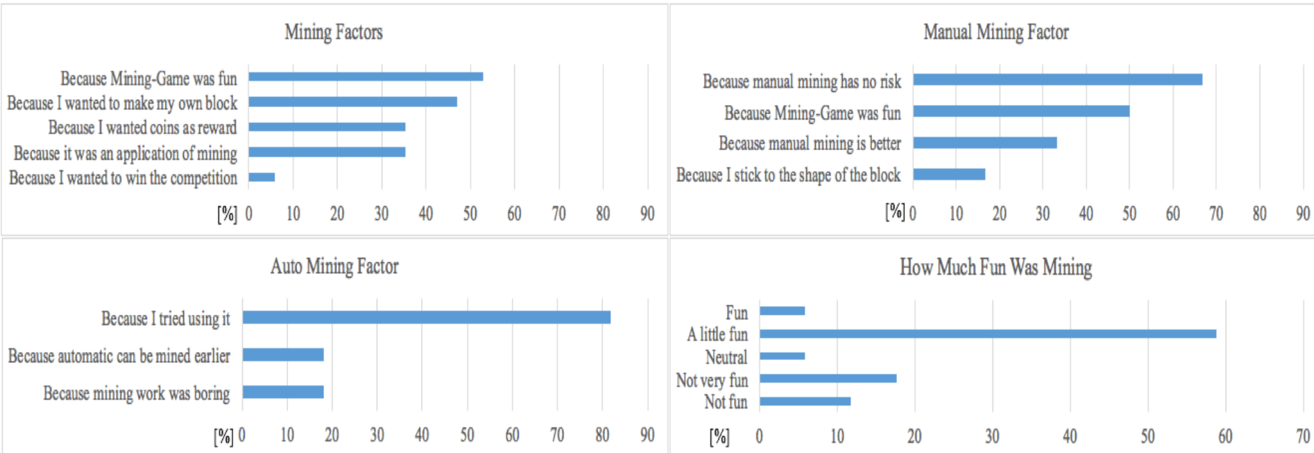

Figure 3. Miming Factor: Q1, Manual-Mining Factor: Q2, Auto-Mining Factor: Q3 and Enjoyment of Mining: Q4

The statistical data were compiled with respect to the items listed below; the number of generated blocks, the number of mining work done manually and automatically.

4.2 Questionnaire

In the questionnaire, we investigate whether the service actually provided incentives that are based on the psychological factors. The contents of the question used in the questionnaire are shown below as Q1 - Q9.

Q 1) What is the reason for thinking about mining work?

Q 2) This is a question to those who have not done automatic mining work even once. What is the reason why you did not do it?

Q 3) This is a question to the person who performed automatic mining work. What is the reason why you did it?

Q 4) Have you had fun in mining work?

Q 5) In the case of this design, it seems that you can use the service without getting tired after how many days.

Q 6) The probability of mining work success this time was 1/16. Do you think you would continue mining work with this probability?

Q 7) If the probability of mining work had reached 1/100, would you decide to continue mining work?

Q 8) If the probability of mining work success is 1/10000, would you decide to continue mining work?

Q 9) If you have an opinion on the application, please describe it freely.

5 RESULTS AND ANALYSIS

Table 4, Table 5, Fig. 3, and Fig. 4 show the results of the experiments and the questionnaire obtained and also discuss the feasibility of solving the mining work concentration problem from the experimental results.

5.1 About Motivating Factors

The section considers what a participant felt motivated to mining work. Focusing on the answer to Q1, 52.9% participants accounted for "Mining work itself was fun." from Figure 3 (a). The answer is relevant to Q4; most of participants enjoyed the mining work. Also, 47.1% of participants said "I wanted to build my own block and wanted to join the block. Because I wanted a reward.", and "It was told to me to do the mining work." for 35.3% of participants. This means that roughly half of the participants were motivated to do mining work through gamification. Similarly, some participants were motivated through economic rewards like Bitcoin, or the intrinsic motivation to contribute the service's operation. However, 35.3% of participants responded that "I was told to do the mining work", which can be inferred as a participant who could not have motivated the mining work through gamification. In addition, 5.9% of participants answered "I wanted to win the mining work competition." This means that there are a few participants who were motivated through social incentives like the competition to solve a puzzle.

Since the virtual currency used in this service is the currency generated for the experiment, and it was not accompanied by actual monetary value, the difference caused by the design decision is also necessary to be taken into account. In the free description in Q9, some were answers such as "Because there was no value of coin"; the motivation to collect coin did not rise so much.", or "I thought that motivation would change if the reward was directly returned to participants."

TABLE 4. THE NUMBER OF BLOCKS GENERATED

Manual	Auto
542	277

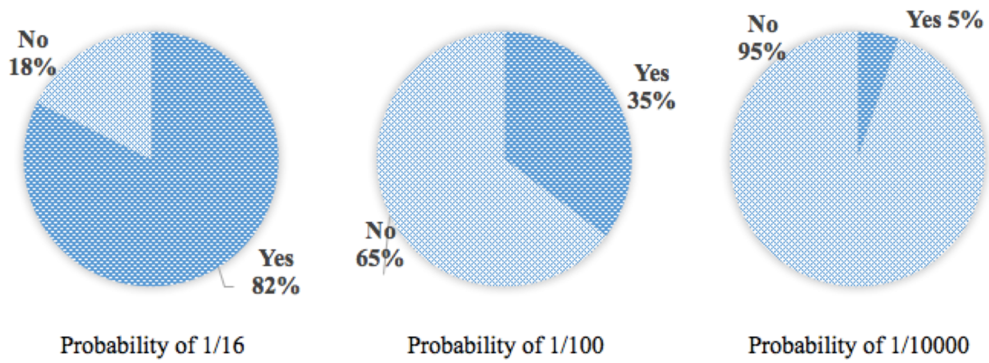

Figure. 4. Proportion trying to continue manual mining work, with probability of (a)1/16, (b)1/100, and (c)1/10000

TABLE 5. HOW LONG DO YOU WANT TO USE THE SERVICE ?

Time	Response Rate [%]
1 day	11.8
2,3 day	17.6
4-7 day	52.9
2,3 week	11.8
1 month	5.9
Over 1 month	0

If the currency used here is a currency with monetary value, it can be inferred that the options that can affect the answer result of Q1 include "I wanted a reward.", "Because I was told to do the mining work." Since these options are all related to the incentive by an external factor based on "currency", it can be considered that it is independent of the incentives by psychological factors using gamification.

5.2 Effects of Gamification

This section discusses whether the game elements offered by gamification used for the service were given incentives from psychological factors to participants. The game element used in the service was to associate the nonce value in the block with the shape of the puzzle. Focusing on the answer to Q4, as shown in Figure 3 (d), the percentage of participants who actually felt pleasure with mining work was 65%, and the percentage of participants who did not feel fun was 35%. In other words, it can be said that more than half of the participants had motivation for the game elements in the service.

We also try to perform a comparison between automatic and manual mining work. From Table 4, the number of total blocks generated during the experiment was 819, among which 542 blocks by manual mining work and 277 blocks by automatic mining work were found. That is, 66% of the blocks are manually created. This ratio generally agrees with the proportion of participants who felt pleasure with respect to the mining work incorporating game elements. Looking at the answer to Q2, half of the participants answered "Because I wanted to do mining work in my hand." This is the reason why they did not use automatic mining work from Figure 3 (b). Also, looking at the answer to Q3, 80% of participants answered "I used it just as a trial." as the reason for using automatic mining work from Figure 3 (c). On the other hand, since 20% of participants answered that "Mining work was troublesome." It can be inferred that most participants accounted for mining work as games instead of monotonous work.

In summary, it is concluded that it is effective to give incentives due to psychological factors using gamification to mining work.

5.3 Application to Cryptcurrency

This section considers whether the mining work using gamification can be applied to realistic cryptographic currency using the blockchain technology. In the service used in this paper, we defined the success probability to do mining work as 1/16. According to this probability, if a participant can continue using the service or looking at the answer to Q6, 82% of participants answered "I think I can continue." from Figure 4 (a). On the other hand, if looking at the answer to Q7 whether a participant seems to continue mining work when the probability to do mining work successfully is 1/100, 35% of participants from Figure 4 (b) replied "I think I can continue." Also, if looking at the answer to Q8 whether a participant seems to continue mining work when the probability to do mining work has become 1/10000, only 5% of participants answered "I think I can continue." from Figure 4 (c).

From these answers, it was found that the lower the success probability of mining work, the less motivated a participant to do mining work. For example, since the success probability of performing mining work in Bitcoin is $1/10^{21}$as of January 2017 [2], it can be said that it may be impractical to apply the game element of this service applied to mining work in Bitcoin. However, as mentioned above, the service can be used by "fun by game" as a motivational factor; it seems likely to be able to provide machine power using gamification without direct mining work. In other words, it seems to be effective when giving participants mining work as puzzles or games as incentives to provide machine power.

We still need to consider how to make puzzles and game designs more effective and what kind of design you should not get bored with in order to keep participants providing machine power, and we will conduct more experiments to justify the proposed approach.

5.4 Feasibility of Solving Mining Work Centralization

This section discusses whether we can actually solve the mining work centralization problem by increasing the number of participants who perform mining work, which is achieved by offering incentives based on psychological factors using gamification. In this section, solving the mining work centralization problem is defined as more than 10% of mining work in the entire blockchain being performed by participants motivated through gamification; this is based on the actual data in Bitcoin to demonstrate the proposed approach's feasibility in a practical usage environment.

First, we estimate how much machine power will be gathered due to the psychological incentive based on gamification. Looking at the answer to Q5 in order to investigate the period that the service can be used continuously, from Table 5, we found 11.8% for 1 day, 17.6% for 2-3 days, 52.9% for 4-7 days, 11.8% for 2-3 weeks, and 5.9% for 1 month. On average, it seems that people can continue to use the gamified mining work for one week per person. Also, we consider the startup count of the service. Since the number of participants in the experiment was 44, assuming that it was started 7 times per person, it can be roughly estimated that 308 services were started in total. Since the number of blocks generated during the experiment period is 819, 2.66 blocks are generated by starting a service once. Since the time required to generate 2.66 blocks is approximately 10 minutes, we approximate the amount of machine power that can be provided using the above consideration.

Regarding Bitcoin, it is stated that roughly 2140 is about to reach the upper limit of issuing currency due to mining work [12]. Therefore, we thought that it would be necessary to continue providing machine power for roughly 100 years. Then, a scenario is considered where the machine power is provided by 10 [minutes] × 7 [times] = 70 [minutes] = 4200 [sec] per person from the above discussion. Assuming that the machine power of the computer used by a user is 2 GHz and the ratio of the machine power that can be used for mining work is 20%, the machine power of $2 \text{ x } 10^9 \text{ x } 0.2 \text{ x } 4200 = 1.68 \text{ x } 10^{12}$ [cycle clock] per user can be provided. That is, the total machine power that can be newly provided for Bitcoin is $1.68 \text{ x } 10^{12}$ [cycle clock].

Lastly, we estimate the machine power necessary to occupy more than 10% of the mining work ratio in Bitcoin. Currently, the probability of success of mining work in Bitcoin is approximately $1/10^{21}$ [3]; then, we approximate the necessary machine power to perform 10% of mining work based on the above success probability. Then, we calculate minimum n (trials) satisfying $\left(1 - \frac{1}{10^{21}}\right)^n < 0.9$, and the result is $n \text{ x } 10^{24}$ [times]. For the number of trials, the machine power that is required to process one block should be provided. The degree of difficulty is adjusted so that blocks in Bitcoin are generated at a rate of one per 10 minutes. Since the number of blocks generated in 100 years is $6 \text{ x } 24 \text{ x } 365 \text{ x } 100 = 5256000$ [pieces], the total machine power required to solve the mining work concentration problem is $10^{24} \text{ x } 5256000 = 5.256 \text{ x } 10^{30}$ [cycle clock].

6 CONCLUSION

In this paper, we proposed encouraging participation in mining work activities by incentivizing users through psychological factors made available by gamification; the objective was to solve the mining work concentration problem. When it comes to make a user perform mining work directly, since the probability of the approval work succeeding is deeply related to motivation, it does not work on such a design. However, the extracted insights show that it is beneficial to use ubiquitous machine power by giving the user a gaming element.

However, it becomes clear that more machine power is needed to realize the proposed approach. In order to solve the issue, it is necessary to increase the machine power used by the individual. For example, if the personal machine contains powerful Application Specific Integrated Circuit (ASIC) dedicated to mining work, the possibility of solving the mining work centralization problem is increased. There is also room for improvement regarding the gaming design. In the service used in this research, it was expected to launch 70 minutes of a service per user, but by changing the gaming design, the time launching the service with machine power provided may be increased significantly.

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