Research on the Establishment of a Subway Safety Hazard Monitoring System Based on Blockchain Technology

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Abstract: Currently, there are challenges in the safety management of subway construction, such as time-consuming monitoring of safety hazards, poor authority, poor traceability, or lack of real-time information. To address these issues, this study developed a new blockchain based security hazard monitoring system (SHMS) and constructed a blockchain for sharing and managing security hazard information, allowing each monitoring party to participate in risk monitoring. Finally, its main scientific contributions were discussed and summarized.

Keywords: Safety Hazards; Metro construction; Safety Hazard Monitoring System; Blockchain

1 Introduction

Subway engineering is complex, unpredictable, and uncertain, especially tunnel shield tunneling, which has high concealment and higher risks. Accurately and comprehensively grasping the potential risks of subway construction is crucial, and real-time warning should be provided to reduce the probability of accidents[1]. Reducing safety risks and accidents during subway construction relies on monitoring safety hazards. Describing safety hazards related to management, environment, machinery, and personnel in subway construction may be challenging. Traditionally, the procedure for subway safety guidance is as follows: experienced subway engineers or technicians conduct inspections and records in third-party systems[2]. They outline the current status of various structures, site environments, and equipment. This process mainly relies on individual subjective engineering experience, which is reflected in many engineering examples. Therefore, in order to improve the accuracy and reliability of early warning of safety hazards, the goal is to maximize the availability of safety conditions on the construction site.

In addition, the current safety hazard screening system is also challenging to achieve through real-time data monitoring and integration of safety hazards. Due to the involvement of third-party systems, they lack tamper resistance, real-time performance, and confidentiality. This article applies blockchain technology to the safety warning management process of subway projects, integrates warning functions into smart contracts, and conducts research on the goals, content, and risk assessment warning of tunnel and subway construction safety management. Given the limitations of existing monitoring models, this paper designs an safety

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hazard monitoring system(SHMS) based on consortium blockchain. This not only ensures that a single monitoring station enters the consortium blockchain of each node, ensuring the free exchange of information between both parties and ensuring the privacy of the communication process, but also saves a large amount of information generated during the entire construction monitoring process.

2 The SHMS construction

This article aims to solve the problem of establishing a set of key technologies based on blockchain technology, implementing a security hazard investigation system. Blockchain mainly stores security hazard regulations in the blockchain, and then uses real-time monitoring technology to establish safety hazard monitoring system. The overall framework is shown in Fig. 1. safety hazard regulations storage system categorizes, integrates, and stores safety hazard regulations. safety hazard monitoring system aims to address the issue of unconditional access to security regulations in blockchain, allowing all parties to monitor the subway construction process in real-time and exchange various information. This article will mainly focus on the research of SHMS.

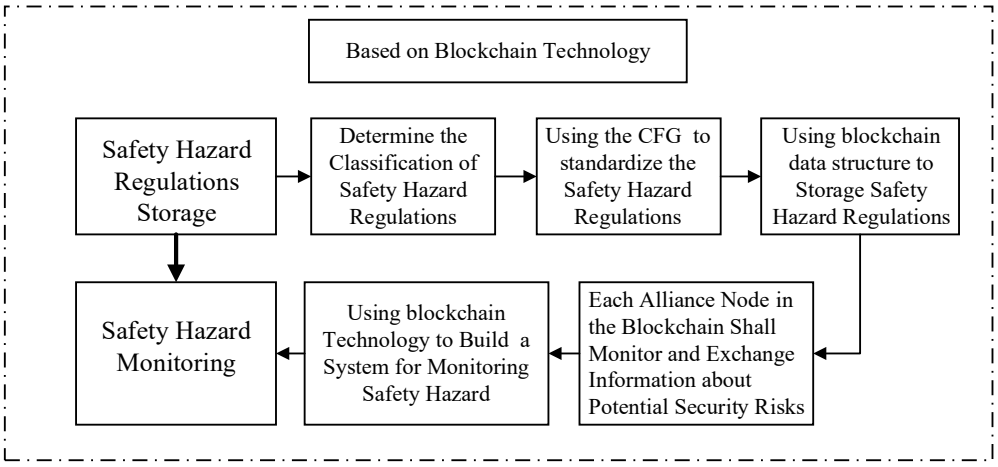

Fig. 1. Research Framework

2.1 Safety hazards monitoring information exchange on Blockchain

According to the degree of openness, the blockchain is divided into three categories: public, consortium, and private. The public blockchain is entirely decentralized; any node can access the chain and enjoy equal rights[3]. The private blockchain adopts a centralized system, opens only to specific nodes, and requires permission to read and write information. The consortium blockchain is in between, namely combined with the public blockchain, highly available time with private blockchain highly centralized privatization. The consortium designated several nodes in advance[4]. After to join the node wants to join the consortium blockchain, all need to apply for and verify after agreeing to join the consortium blockchain.

Because the danger faced by the metro construction process is multi-dimensional, it is the network of each monitoring party as nodes. Therefore, using the consortium chain form for information sharing during the construction monitoring process can ensure the rapid processing of a large amount of information. The incomplete centralized structure can provide an equal relationship between the various monitoring parties[5]. According to the different parties in the metro construction monitoring consortium, the consortium nodes in the blockchain are divided into personnel monitoring nodes, mechanical monitoring nodes, administration monitoring nodes, and environmental monitoring nodes. Each node after the verification, gets the corresponding node identity IP, then gets the IP of each node calculation and generates its public key and private key, their parameters information, and critical public broadcast to the entire network. Moreover, obtain and save other nodes' data from participating in the metro hazard monitoring consortium organization, all around the project cooperation.

Each node in the consortium blockchain needs to provide information integrated from various departments within the node. The info the personnel monitoring nodes provide includes whether the construction personnel's operation is standardized, whether the construction personnel has received safety training, and whether the project manager is on duty[6]. The mechanical monitoring nodes include the scaffold operation parameters and whether the crane tower's use is standardized. Other essential elements of the administration monitoring nodes provide information about the operation, management, and safety education schemes[7]. Furthermore, the information the environmental monitoring nodes provides includes the construction environment, weather state, and workers' living environment, among other things.

For each data completed by the monitoring task, the hash value is generated by the hashing algorithm for a fixed time[8]. If the interval is brief, the hash value of all contracts can be retained and related directly to the Merkle root in the block header. In many security risks and the number of parties involved in the metro construction, the original recorded hash value must be further hashed and repeatedly iterated until the block storage requirements are met. Then the final hash value is linked to the Merkle root[9]. The hashing process of links to the Merkle root is stored in the block that each data is traceable, while the unidirectional and conflict resistance improve the reliability of the data. The block header records the latest versions, the previous address, timestamp, Merkle root, and partial scoring information through the last address block and the current block's data hash.

According to the relevant definition of blockchain and the safety hazard regulations storage system, the conceptual model of monitoring blockchain for constructed metro construction is shown in Figure 2.

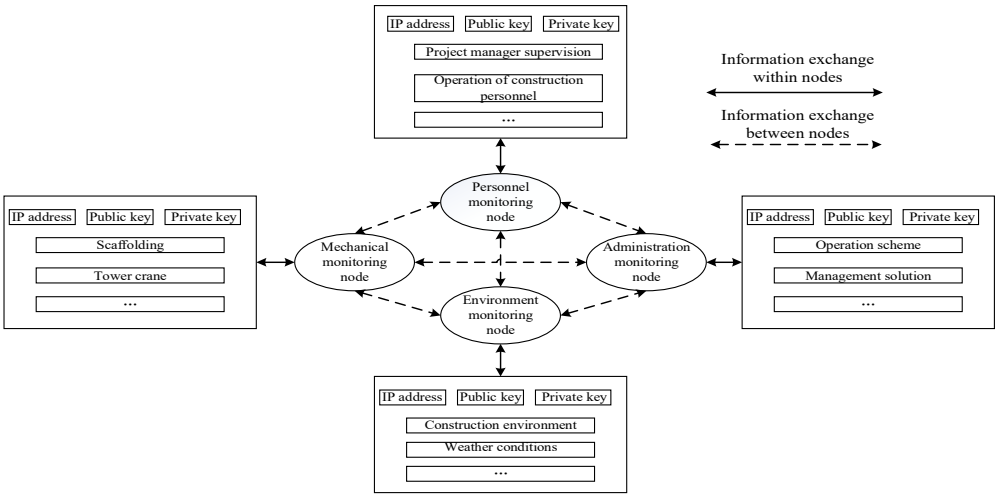

Fig. 2. Consortium node of metro construction monitoring blockchain

2.2 Monitoring model of safety hazards

The blockchain generation process of the predicted security risk management blockchain is as follows:

Step 1: Each monitoring party of the metro construction project shall jointly set up a consortium node, validate and add the new nodes, obtain the public key and the private key as the identity authentication, and determine their authority[10].

Step 2: Each node selects the authorization node by using the consensus mechanism.Randomly select a starting point from the security risk status information to start matching. After successful matching, use smart contract technology in blockchain to create a contract, and then store the contract information on the block for automatic execution.

The calculation method for matching probability p is shown in formula (1):

If the k-th ant starts with state information i, then the matching probability p with rule j

$$\mathrm{p}_{\mathrm{k}}(i,j)=\begin{cases}\arg\max\{[\tau(i,j)]\times[\eta(i,j)]\}, j\in J_k(i)\\ 0, \text{other}\end{cases} \tag{1}$$

In the formula, τ (i, j) is the pheromone between safety hazard information i and rule j, and Jk (i) is the collection of all safety hazard status information. η (i, j) are heuristic factors that affect the status information of safety hazards.

Step 3: The consortium nodes shall monitor their safety risks and commit to completing the task. This commitment defines the rights and obligations of the parties, which the private keys of both parties shall sign. The P2P network translates the contract into the corresponding code, verifies it, and broadcasts the result to the entire network. The authorized node sends it over the blockchain.

Step 4: Smart contract, in the process of execution, state information moment record the metro construction status. After the monitoring, personnel monitoring, management monitoring, mechanical monitoring, and environmental monitoring information verification, verification by the authorized node information is temporarily stored in the transaction database and spread to other nodes.

Step 5: The transaction database's data is verified by the smart contract every once in a while. The contract terms are executed once the contract's criteria are met, outcomes of the contract execution generate a new block. It is connected to the chain tail of the existing blockchain to form a complete metro construction monitoring blockchain.

Step 6: After the blockchain has been generated, when a node needs to add, delete, query, or test the information, it must issue a request to the node's network, and then the corresponding parties will solve it.

3 Conclusions

Safety hazard monitoring is an important control means in metro construction. During the monitoring stage, each participant will produce information. Based on blockchain technology, each alliance can promptly communicate and share information on the site. SHMS can effectively solve the problems of lack of trust, difficulty in supervision and traceability, and information security among the participants in metro construction.

The system provides the premise for complete monitoring of metro construction and automatic hazard identification in the later stage of the project. In metro construction, the safety regulations stored in the blockchain are used for analysis and judgment to share timely and effective monitoring information. The site staff is informed about using timely strategies to control safety.

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