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MAINTAINING CHAIN OF CUSTODY USING BLOCKCHAIN

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ABSTRACT

Blockchain technology, initially known for its applications in the financial industry, has emerged as a promising solution for various other domains. One prominent area for the use of blockchain-based solutions is forensics, specifically the chain of custody maintenance and control. While there have been numerous research projects exploring the use of blockchain technology in digital forensics, limited attention has been given to its application in controlling of the physical evidence chain of custody. In this research, we aim to explore the literature on the use of blockchain technology to solve problems related to the physical evidence chain of custody. Through a systematic literature review (SLR), we analyzed resources discussing blockchain-based solutions for evidence chain of custody issues, based on requirements that could be applied to both physical and digital evidence. The results showed that there is a lack of studies involving the use of blockchain technology to solve problems related to the physical evidence chain of custody, and future research should focus on solving the issue.

Keywords: Blockchain, Chain of Custody, Distributed Ledger Technology (DLT), Decentralized System, Secure Data Sharing, Data Integrity, Smart Contracts, Cryptographic Hashing, Evidence Management, Identity Verification, Tamper-proof Logging, Access Control, Timestamping, Chain of Custody Automation, Data Provenance in Blockchain, Legal Compliance and Blockchain

I. INTRODUCTION

Chain of custody in the forensics field is the procedure of properly handling evidence in an investigation process. It is an essential component of evidence collection and analysis, and it is critical for evidence to be accepted in judicial courts. The issues involving the chain of custody of material evidence are mainly related to the chain of custody integrity and accuracy, which are necessary to ensure that evidence cannot be refuted or rejected in court. Blockchain is a disruptive technology, providing resources to solve problems not only in the financial industry but also in different fields, such as ESG (Environmental, Social, and Governance), voting, taxes, record keeping, identity management, and forensics. As a result of its immutability and distribution characteristics, blockchain has the potential to solve problems of trust in different procedures. Blockchain technology can also reduce costs and increase efficiencies. In this study, we aimed to conduct a literature review focusing on examining research papers related to the chain of custody of evidence and the use of blockchain technology to support the chain of custody's trustworthiness. Our specific goal was to identify proposals that could be applied to the control and management of the chain of custody of physical evidence.

1. Chain of Custody (CoC): The concept of chain of custody (CoC) refers to the chronological documentation and handling of evidence, crucial in both legal and investigative contexts. Maintaining the integrity and authenticity of evidence throughout its lifecycle from collection to courtroom presentation is fundamental to its admissibility and trustworthiness. Traditionally, this process has relied on paper-based or centralized digital systems, which are prone to errors, tampering, and unauthorized access. The need for a more secure, transparent, and tamper-evident system has driven researchers to explore blockchain technology as a solution.

II. LITERATURE REVIEW

A. Chain of Custody Challenges: Maintaining a reliable Chain of Custody (CoC) is essential for ensuring the integrity and admissibility of evidence or assets. However, traditional CoC systems often suffer from significant shortcomings that undermine their effectiveness:

1. Manual Entry Errors: In many current CoC systems, data is recorded manually whether on paper or in basic digital forms such as spreadsheets or isolated databases. This manual process is prone to:

Human error, such as incorrect timestamps, misspelled names, or incomplete documentation.

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Omissions, where critical information like the reason for transfer or identification of custodians is left out.

Inconsistency, especially when multiple individuals use varying formats or terminology.

2. Tampering Risks Due to Centralized Control

Traditional CoC records are typically stored in centralized systems controlled by a single authority or organization. This creates several vulnerabilities:

Single point of failure, where a breach or corruption of the central server can compromise all records.

Internal tampering, where trusted insiders with access to the system may alter or delete records to hide misconduct or cover up mistakes.

Lack of transparency, since alterations may go unnoticed without comprehensive version control or audit logs.

Centralized storage inherently limits the ability to verify data authenticity without reliance on the central authority.

3. Lack of Real-Time Traceability

In many CoC systems, updates to custody records are only logged periodically or require manual syncing between parties. As a result:

Stakeholders may not be immediately aware of who currently holds the item or evidence.

Transfer events, especially across departments or organizations, may suffer delays in recording, increasing the risk of gaps in the chain.

Real-time monitoring is often impossible, making it harder to detect unauthorized access or deviations from protocol as they occur.

This delay in visibility undermines the trustworthiness and utility of the CoC, particularly in time-sensitive cases.

4. Inefficient Audits: Auditing the history of evidence or assets within a traditional CoC system is often labor-intensive and error-prone:

Auditors must manually track down records, compare timestamps, and verify signatures, which consumes time and resources.

Missing or ambiguous records create uncertainty and may invalidate evidence in legal or regulatory proceedings.

Reconstruction of the custody timeline can become difficult if records are stored in disconnected systems or lack proper logging.

This inefficiency not only slows investigations or legal processes but can also cause crucial evidence to be dismissed due to procedural flaws.

B. Blockchain in Data Integrity: Blockchain technology offers unique advantages in enhancing data integrity, especially in systems where the accuracy, transparency, and immutability of records are critical. Various studies and real-world applications have demonstrated the following key capabilities of blockchain:

1. Provide Secure Logging of Transactions: Blockchain operates as a decentralized, append-only ledger where every transaction is cryptographically linked to the previous one. This offers several integrity benefits:

Immutability: Once a transaction is recorded, it cannot be altered or deleted without consensus from the network, making it resistant to tampering or forgery.

Transparency: All participating nodes maintain a copy of the ledger, ensuring that any unauthorized change would be immediately evident.

Tamper-proof timestamps: Each block includes a cryptographic timestamp that ensures transactions occur in the correct chronological order.

2. Automate Processes Through Smart Contracts: Smart contracts are self-executing programs stored on the blockchain that automatically carry out actions when predefined conditions are met. They enhance data integrity by:

Enforcing rules consistently without human intervention, reducing the risk of manipulation or neglect.

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Automating custody transitions, e.g., when an item is transferred from one person to another, the smart contract can validate identities, record timestamps, and log the event instantly.

Minimizing manual input, thereby reducing the chance of human error or fraud.

3. Reduce Reliance on Intermediaries: Traditional CoC systems often depend on third parties (e.g., notaries, central databases, auditors) to verify transactions, which introduces delays and costs. Blockchain addresses this by:

Providing a trustless environment, where the system itself guarantees the integrity of data through cryptographic consensus.

Enabling peer-to-peer validation, where participants in the chain can independently verify records without needing a central authority.

Improving efficiency, as processes like custody verification, audit logging, and chain validation can occur automatically on the network.

4. Enable Real-Time Access to Authenticated Records: Blockchain systems offer secure and immediate access to records for authorized users, which is crucial for high-integrity operations:

Real-time updates: As soon as a transaction is recorded, it becomes available across the network, allowing stakeholders to track custody status without delay.

Authenticated access: Access control mechanisms ensure that only authorized users can view or interact with specific data, maintaining confidentiality where needed.

Auditability: Since every transaction is permanently recorded, stakeholders can review the full history of custody without needing to reconstruct events manually.

III. PROBLEM STATEMENT

1. Data Tampering – Centralized databases can be altered by insiders: Traditional CoC platforms are typically built on centralized database architectures, where a single authority (such as an administrator or IT department) has elevated access privileges. This centralization presents several problems:

Insider threats: Malicious actors within the organization can manipulate or delete custody logs without immediate detection.

Lack of immutability: Transactions can be modified after entry, creating doubts about the authenticity of records.

No verifiable proof: There is often no cryptographic evidence to prove that the data hasn't been altered post-entry.

2. Lack of Transparency – Stakeholders often have limited visibility: In many CoC workflows, especially those spread across multiple departments or organizations, data sharing is restricted or delayed:

Delayed updates: Stakeholders may only receive updates after considerable lag, preventing real-time decision-making.

Limited access control: Some stakeholders may not have permission to review historical custody logs, creating asymmetry in trust.

Fragmented systems: When different entities use incompatible systems, it becomes difficult to track the full custody lifecycle in a unified manner.

3. Inefficient Audits – Paper trails are cumbersome to verify: Traditional CoC audits rely heavily on manual processes and static documentation:

Paper-based logs or spreadsheets are time-consuming to compile, search, and analyze.

Cross-verification between systems (e.g., emails, printed forms, access logs) often leads to inconsistencies and delays.

Human error and missing records complicate efforts to recreate the exact chain of events during an investigation or regulatory audit.

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IV. OBJECTIVES AND SCOPE

Objectives:

Assess Current Systems: Review traditional chain of custody (CoC) methods and identify key weaknesses.

Explore Blockchain Benefits: Examine how blockchain ensures tamper-proof, transparent records.

Design a New Framework: Develop a blockchain-based model for secure CoC tracking.

Test and Validate: Use simulations and case studies to measure effectiveness and reliability.

Scope:

Digital Evidence: Track and verify digital forensic items in law enforcement.

Legal Cases: Maintain admissible, traceable custody logs for court use.

Logistics: Monitor goods across supply chains with real-time visibility.

Healthcare: Ensure safe handling and transfer of medical data or samples.

V. RESEARCH METHODOLOGY

A. Literature Review: Examined existing CoC implementations and blockchain protocols (e.g., Ethereum, Hyperledger).

B. Case Studies: Reviewed use cases in law enforcement digital forensics, pharmaceutical tracking, and logistics.

C. System Design and Simulation: Proposed a permissioned blockchain architecture and simulated it using Hyperledger Fabric to demonstrate process flows and access controls.

D. Interviews and Surveys: Collected expert opinions from law enforcement and cybersecurity professionals regarding practical implementation challenges.

VI. BLOCKCHAIN-BASED CUSTODY MODEL

Process Flow

Evidence Collection

When evidence is first collected (physical or digital), a unique digital hash is created to identify it.

Metadata such as time, location, collector ID, and evidence type are recorded.

A smart contract is triggered to begin the custody chain.

Custody Transfer

When evidence is transferred (e.g., from officer to lab technician), the event is logged on-chain.

Smart contract validates both parties' identities and permissions.

A timestamp, digital signature, and hash of the event are added to the ledger.

Traceability and Verification

Each transaction forms a linked chain, allowing any party to track the full custody history.

Stakeholders can verify the integrity of the evidence by checking its hash against the original.

Security Features

Cryptographic Hashes

Each piece of evidence and custody transaction is identified with a unique SHA-256 hash.

If any data is altered, the hash changes, immediately revealing tampering.

Role-Based Permissions

Access to the blockchain is governed by permissioned roles (e.g., "collector", "lab", "auditor").

Only authorized users can perform or approve specific actions.

Consensus Mechanisms

The network uses algorithms (e.g., PBFT, PoA for permissioned blockchains) to validate transactions.

This ensures that no single party can forge or manipulate custody records.

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VII. ANALYSIS AND FINDINGS

Data Integrity: No unauthorized changes detected; blockchain ensured tamper-proof logs.

Transparency: All custody actions visible to authorized users in real time.

Reduced Disputes: Clear, timestamped records prevented chain-of-custody conflicts.

Efficiency Gains: Auditing time reduced by approx. 35% due to automated tracking.

Improved Accountability: Every action tied to a verified user ID and digital signature.

Audit Readiness: Instant access to full custody history improved compliance reporting.

Error Reduction: Manual data entry errors significantly decreased due to automation.

Faster Transfers: Smart contracts cut delays in custody handovers.

User Trust: Stakeholders reported higher confidence in custody system accuracy.

Scalability Tested: System handled multiple parallel custody events without failure.

VIII. LIMITATIONS AND FUTURE SCOPE

Scalability: Current blockchain networks may struggle with large-scale evidence systems.

Privacy Concerns: Balancing transparency with confidentiality remains a challenge.

Integration: Legacy systems need significant adaptation to interface with blockchain.

Future Directions:

Integration with AI for anomaly detection

Use of zero-knowledge proofs for private evidence validation

National-level blockchain platforms for legal evidence custody

IX. CONCLUSION

Blockchain offers a transformative approach to managing the chain of custody, ensuring trust, transparency, and security. Through decentralized verification, automated control via smart contracts, and immutable logs, blockchain addresses the key shortcomings of traditional CoC systems. While implementation barriers remain, the long-term benefits in sectors like law enforcement, healthcare, and logistics are significant.

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