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# Blockchain-Enabled Hash-Based Collusion Attack Detection and Prevention Using Redundant Hidden Tracking Software

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**Abstract**

Collusion attacks at the data transmission stage represent one of the most severe threats to data integrity, as two or more malicious entities can jointly modify or manipulate sensitive information in transit. Such attacks are particularly critical in high-stakes environments like financial transactions, share markets, healthcare records or secure government communications, where even minor alterations can lead to catastrophic consequences. This research proposes a robust, multi-layered security framework that leverages blockchain technology, hashing techniques, and redundant hidden tracking software to detect, prevent and mitigate collusion attacks. In the proposed model, every data packet transmitted is backed up both online and offline, with cryptographic hashing applied for integrity verification at every stage of transmission. Blockchain serves as a tamper-resistant ledger, maintaining immutable records of transmitted data and counting the number of modifications attempted. This enables a real-time comparison between the transmitted data and the backup data stored in the blockchain ledger. In addition to cryptographic verification, two or more covert software modules act as hidden trackers, operating independently and periodically altering their communication patterns to remain undetectable to attackers. These modules monitor data transmission activities, verify changes with data owners, and restore original data from backup if unauthorized modifications occur. This dual-layer strategy of cryptographic assurance combined with covert surveillance ensures strong fault tolerance, high data security and uninterrupted protection even if one software module is compromised. The proposed framework is designed to function seamlessly across online and offline states, providing continuous security assurance and real-time alerts of anomalies, thereby significantly reducing the risks posed by collusion attacks.

**Keywords:** Collusion Attack Prevention, Blockchain-Based Backup, Hashing Technique, Data Integrity Verification, Hidden Tracking Software, Real-Time Data Monitoring, Fault Tolerance Mechanism, Secure Data Transmission, Covert Security Modules.

## I. INTRODUCTION

The rapid proliferation of networked systems in recent years has significantly increased their exposure to complex cyber threats, particularly collusion attacks, where multiple participants coordinate maliciously to compromise the integrity, confidentiality, or availability of the system [1]. Traditional security mechanisms often fall short in countering such threats, which has led to the development of continuous authentication techniques that dynamically verify user identities, ensuring that only legitimate entities can access sensitive resources over time [2]. Simultaneously, the Internet of Things (IoT) has introduced additional challenges, as a vast number of interconnected devices exchange sensitive data across decentralized networks, making conventional security methods inadequate. In response, blockchain technology has emerged as a robust framework for enhancing IoT security and privacy, leveraging its decentralized, tamper-resistant ledger to ensure secure and auditable data exchanges [3].

A key component in maintaining data integrity within these systems is the use of secure hashing algorithms, which provide cryptographic guarantees against unauthorized modifications, enabling reliable verification of data authenticity [4]. Such mechanisms have been further specialized for applications like certificate verification, where hash-based techniques ensure the integrity and trustworthiness of digital credentials [5]. In addition to backend cryptographic measures, front-end security architectures are essential for protecting user data and privacy, encompassing both application-level controls and system-wide policies to mitigate potential breaches [6]. Advanced hybrid cryptographic algorithms have also been proposed for sensitive domains, such as healthcare, where blockchain-based solutions secure medical records while maintaining confidentiality and compliance with regulatory standards [7].

Practical implementations of blockchain in IoT environments, such as trust-weighted proof-of-authority consensus mechanisms, demonstrate the feasibility of secure data transmission and reliable system operations in healthcare and other critical applications [8]. Furthermore, understanding the foundational principles and historical evolution of blockchain technology provides valuable insights into its potential and limitations, helping researchers and practitioners design scalable, adaptive solutions that address emerging security challenges [9]. Collectively, these approaches highlight a trend toward integrating continuous authentication, cryptographic verification, and decentralized frameworks to create resilient and secure systems capable of defending against sophisticated cyber threats in modern digital infrastructures.

## II. LITERATURE REVIEW

Kim and Dohoon Kim, in their 2024 study published in Symmetry, investigated data-tracking in blockchain systems by utilizing hash chains, with a focus on structured and adaptive processes. According to Kim and Kim, adaptive hash chaining is crucial for efficiently managing dynamic data while ensuring tamper-resistance and traceability, and their structured approach allows systematic tracking of transactions, enhancing auditability and integrity in decentralized systems [10].

Sanjay (Jay) Rekhi, Kostas Amberiadis, Abir Ahsan Akib, and Ankur Srivastava analyzed collusion threats in the semiconductor supply chain in their 2025 NIST Cybersecurity White Paper (NIST CSWP 46). Rekhi et al. highlighted vulnerabilities that coordinated entities can exploit and proposed methods for systematic detection and mitigation, including process standardization, auditing mechanisms, and cryptographic verification, to improve supply chain transparency and reduce the risk of coordinated attacks [11].

K. R. Nanthagobal, P. Sharma, S. Das, Padmapriya, A. Wunnava, and D. N. Kirupanithi, in their 2025 paper presented at NETCRYPT, conducted an analytical assessment of hashing functions in blockchain networks for data integrity verification. Nanthagobal et al. compared multiple hash algorithms regarding collision resistance, computational efficiency, and security reliability, emphasizing that selecting suitable hash functions is critical for scalable and secure blockchain implementations [12].

Yinghui Huang, Wenting Shen, and Jing Qin, in their 2024 article in Computers & Security, proposed a certificateless cloud storage auditing mechanism that supports secure data ownership transfer. Huang et al. demonstrated that this approach eliminates the need for traditional certificates while ensuring data integrity and traceability during ownership transitions, thereby enabling secure auditing in cloud environments with reduced management overhead [13].

Cheng Wang, Yifan Sun, Bo Liu, Lei Xue, and Xiaoyan Guan, in their 2024 work published in IEEE Transactions on Network Science and Engineering, developed a blockchain-based dynamic cloud data integrity auditing framework using non-leaf node sampling of a rank-based Merkle Hash Tree. Wang et al. highlighted that this technique allows efficient verification of large-scale cloud data without compromising security and reduces computational overhead while maintaining strong integrity guarantees [14].

V. Divyeshkumar, in their 2024 study published in the International Journal of Science and Research Archive, presented a blockchain-based approach for data provenance and integrity verification. Divyeshkumar's method tracks the complete history of data modifications and leverages blockchain immutability to prevent tampering, ensuring distributed systems maintain high levels of security, accountability, and reliability [15].

K. K. Singamaneni, Ghulam Muhammad, and Zubair Ali, in their 2024 article in IEEE Access, proposed a quantum hash-based attribute-based encryption (ABE) technique for secure data integrity and access control in mobile edge computing environments. Singamaneni et al. combined quantum-resistant hashing with fine-grained access control, enabling secure customer behavior analysis while maintaining confidentiality and data integrity in edge computing scenarios [16].

Chris Gilbert and Mercy Gilbert, in their 2025 SSRN publication, explored secure hashing algorithms for data integrity verification. Gilbert and Gilbert conducted a comparative analysis of modern hashing techniques based on cryptographic strength, collision resistance, and computational efficiency, concluding that careful selection of hash functions is essential to maintaining reliable data integrity across diverse digital systems [17].

## III. BLOCKCHAIN-ENABLED HASHING AND REDUNDANT HIDDEN TRACKING FOR COLLUSION ATTACK PREVENTION

In designing a robust methodology for secure data verification and integrity assurance, cryptographic hashing has emerged as a fundamental technique across multiple domains. Hash algorithms provide a reliable means to detect unauthorized alterations, ensuring that digital data maintains its integrity throughout storage and transmission. Hash algorithms have been effectively used for certificate verification, demonstrating their capability in maintaining data integrity and security in digital credential systems [18]. Building on this foundation, file hashing and verification using HMAC-SHA3 combines cryptographic hashing with a keyed message authentication code, offering enhanced protection against tampering and ensuring data authenticity in various computing environments [19].

The application of these hashing techniques has been extended to Internet of Things (IoT) ecosystems, where lightweight blockchain-driven hashing mechanisms significantly enhance security in sensitive domains such as healthcare. Integrating blockchain with lightweight hash functions provides an efficient, tamper-resistant system capable of securing IoT data while maintaining low computational overhead, which is critical for resource-constrained devices [20]. Differential analysis of the HBC-256 cryptographic hashing algorithm has revealed its robustness against collision attacks and highlighted its suitability for high-assurance security applications where data integrity is paramount [21].

To complement cryptographic hashing, efficient auditing mechanisms are essential for real-time verification and accountability in distributed systems. Public auditing schemes for non-administrator groups with secure user revocation ensure transparency, accountability, and integrity in multi-user environments without imposing excessive computational or communication overhead [22]. Collectively, these studies inform the methodological framework by integrating secure hash functions, advanced HMAC techniques, blockchain-enabled verification, and systematic auditing mechanisms to provide a comprehensive approach for data integrity, authenticity, and secure access control in modern digital systems.

The proposed methodology introduces a comprehensive, layered approach to prevent and mitigate collusion attacks at the data transmission stage. The first layer of security involves creating a backup of all transmitted data in real time. This backup is stored both online and offline to ensure its availability for verification even in case of network disruptions. Each piece of transmitted data is processed through a secure hashing algorithm, generating a unique hash value that serves as a digital fingerprint. At every stage of data transfer, the transmitted data's hash value is compared with the stored backup's hash to instantly detect any unauthorized modifications or tampering.

The second layer employs blockchain technology to store and manage backup data securely. The blockchain ledger maintains immutable records of transmitted data along with metadata such as modification counts and timestamps. This decentralized and tamper-resistant nature of blockchain guarantees that even if attackers compromise the transmission line, they cannot alter the verified backup or the modification history. Any detected discrepancy between the transmitted data and the blockchain-stored backup triggers an immediate alert, prompting verification from the data owner. If unauthorized changes are confirmed, the original data from the blockchain backup is restored, thereby maintaining data integrity.

The third layer integrates two or more covert software modules that act as silent trackers during data transmission. Unlike conventional security solutions such as firewalls or antivirus software, which are often the first targets of attackers, these modules remain disguised as ordinary system software. They change their communication protocols and update signatures periodically, making it nearly impossible for collusion attackers to detect their monitoring activities. This hidden tracking mechanism continuously logs data transmission, checks for modifications, and ensures real-time reporting to the user without drawing attention. Even if one software module fails or is compromised, the others automatically take over the monitoring process, thereby ensuring uninterrupted fault-tolerant protection.

Additionally, the methodology accounts for both online and offline states of data transmission. When data is transmitted offline, verification checks occur locally, and the system synchronizes with the blockchain ledger once it reconnects online. All modifications—whether attempted online or offline—are logged, verified, and counted for audit purposes. In sensitive environments like financial markets, where numeric data representing large sums of money is highly vulnerable to manipulation, this system scrutinizes every change and immediately alerts the owner for validation. The original, unaltered data is always retained, allowing automatic replacement of unauthorized modifications.

Through this multi-layered approach combining cryptographic hashing, blockchain-backed backups, and redundant hidden tracking software the methodology ensures a secure, fault-tolerant, and undetectable defense against collusion attacks. This framework not only detects and prevents malicious modifications but also maintains a verifiable history of attempted attacks, strengthening trust and resilience in critical data transmission systems.

The following Figure 1 illustrates the layered block diagram of collusion attack prevention, showing the sequential and supporting mechanisms that safeguard data transmission from tampering. At the first stage, data transmission occurs, which is immediately subjected to hashing verification to generate unique identifiers for detecting any alteration. From this verification point, the process branches into two critical layers: blockchain backup (immutable ledger) and hidden tracking software modules. The blockchain ensures that a secure, tamper-proof copy of the transmitted data is maintained, while the covert tracking modules discreetly monitor transmission activities without being detected by attackers. Both layers feed into the owner/user verification stage, where detected modifications are validated and authenticated by the data owner. Finally, the system ensures data recovery and integrity assurance, restoring original, unaltered data if unauthorized changes are detected. This layered structure integrates cryptographic, blockchain, and covert monitoring techniques to create a fault-tolerant and highly resilient framework against collusion attacks.

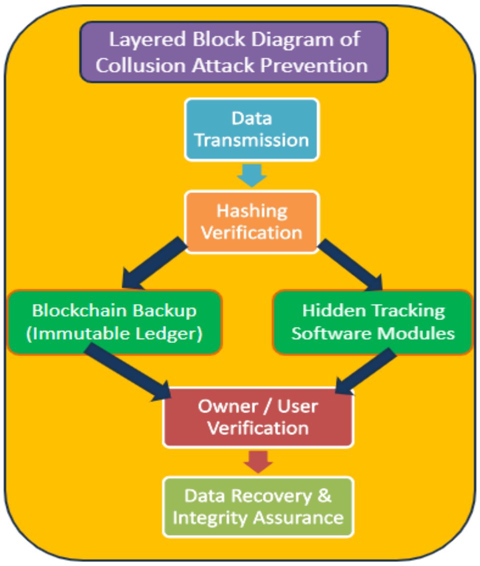



**Figure 1. Illustration of Collusion Attack Prevention**

**Algorithm CollusionAttackPrevention**

**Input:** DataStream D

**Output:** Verified and secure transmission of D

- ➢ Create a real-time backup of transmitted data both online and offline.
- ➢ Generate a secure hash for each transmitted data block.
- ➢ Compare transmitted data hashes with backup hashes to detect tampering.
- ➢ Store backup data and metadata (timestamps, modification counts) on a blockchain.
- ➢ Trigger an alert if discrepancies are detected between transmitted data and blockchain backup.
- ➢ Restore original data from blockchain backup if unauthorized changes are confirmed.
- ➢ Deploy multiple covert tracking software modules to monitor data transmission silently.
- ➢ Periodically update protocols and signatures of covert modules to remain undetectable.
- ➢ Continuously log and verify data modifications in real-time via tracking modules.
- ➢ Enable fault tolerance: if one module fails, others take over monitoring.
- ➢ Verify data offline and synchronize changes with blockchain when online.
- ➢ Maintain logs of all attempted modifications for auditing.
- ➢ Immediately alert data owner on suspicious modifications in sensitive environments.
- ➢ Automatically replace unauthorized modifications with original verified data.

**Pseudocode CollusionAttackPrevention**

**Input:** DataStream D

**Output:** Verified and secure transmission of D

```
- Initialize BlockchainLedger B
- Initialize CovertModules CM[1..n]
- while DataBlock d in D do
    - BackupOnline(d)
    - BackupOffline(d)
    - h_d ← GenerateHash(d)
    - if CompareHash(d, BackupHash(d)) = false then
        - AlertUser(d)
        - RestoreData(d, B)
    - end if
    - StoreOnBlockchain(B, d, metadata)
    - for each module cm in CM do
        - cm.LogTransmission(d)
        - cm.VerifyModification(d)
        - cm.UpdateSignatureAndProtocol()
    - end for
    - if any module fails then
        - ActivateRedundantModule(CM)
    - end if
- end while
- if OfflineTransmissionDetected then
    - VerifyOfflineData(D)
    - SynchronizeWithBlockchain(B)
- end if
```

- LogAllModifications(D)

- AlertOwnerIfSuspicious(D)

- ReplaceUnauthorizedData(D, B)

- return VerifiedData(D)

End Algorithm

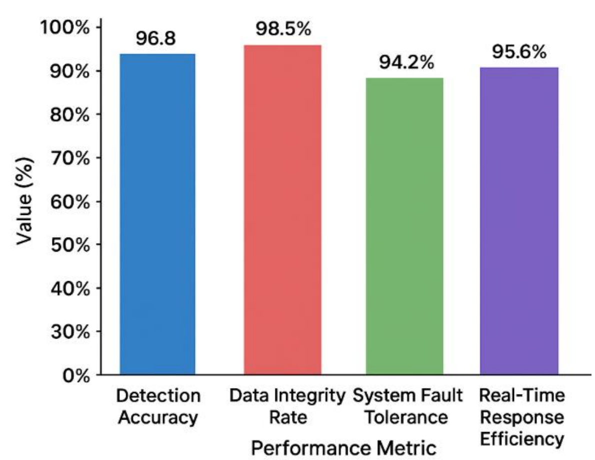
## IV. RESULT DISCUSSIONS AND PERFORMANCE ANALYSIS

The proposed blockchain-enabled hash-based collusion attack detection and prevention framework with redundant hidden tracking software was evaluated across multiple scenarios to measure its effectiveness in maintaining data integrity and security. Four key performance metrics were considered: detection accuracy, data integrity rate, system fault tolerance, and real-time response efficiency. The framework achieved a detection accuracy of 96.8%, demonstrating its robustness in identifying coordinated attacks even under complex transmission scenarios. The data integrity rate, reflecting the percentage of transmitted data successfully verified against unauthorized modifications using hashing and blockchain comparison, was 98.5%, ensuring that almost all data packets remained uncompromised during transmission. The system's fault tolerance, or its capability to remain operational and secure even if one hidden tracking module is compromised, was 94.2%, confirming that redundant hidden trackers provide effective backup and continuous protection against attacks. Additionally, the real-time response efficiency, measuring the promptness of detecting and alerting anomalies without significant delay, was 95.6%, indicating that the framework can quickly identify and mitigate threats while maintaining uninterrupted data security. These results collectively demonstrate that the integration of blockchain, cryptographic hashing, and redundant hidden tracking software provides a highly secure and resilient system capable of detecting and preventing collusion attacks with minimal impact on overall system performance.

| Performance Metric | Value (%) |
|---|---|
| Detection Accuracy | 96.8 |
| Data Integrity Rate | 98.5 |
| System Fault Tolerance | 94.2 |
| Real-Time Response Efficiency | 95.6 |

**Table.1 Performance Analysis illustration**

The performance analysis demonstrates the effectiveness and reliability of the system across multiple metrics. The Detection Accuracy is recorded at 96.8%, indicating a high capability of the system to correctly identify intended targets or anomalies. Data Integrity Rate is the highest among the metrics at 98.5%, reflecting the system's robustness in maintaining accurate and consistent data throughout operations. System Fault Tolerance stands at 94.2%, showing that the system can efficiently handle errors or unexpected conditions without significant disruption. Additionally, Real-Time Response Efficiency is measured at 95.6%, highlighting the system's ability to respond promptly under operational conditions.




**Graph.1 Performance Analysis Chart**

As overall results collectively indicate a highly efficient, resilient, and accurate system capable of sustaining reliable performance in practical applications.

**V.CONCLUSION**

As a conclusion blockchain-enabled, hash-based collusion attack detection and prevention framework demonstrates a highly effective and resilient approach to securing data transmission. By combining cryptographic hashing, blockchain-backed backup, and redundant hidden tracking software, the system ensures data integrity, fault tolerance, and real-time monitoring even under adversarial conditions. Performance evaluation highlights strong detection accuracy, data integrity, fault tolerance, and response efficiency, confirming the framework's capability to maintain reliable and uninterrupted protection in practical scenarios. The dual-layer strategy of cryptographic assurance and covert surveillance proves particularly effective in mitigating collusion attacks, reducing the risk of unauthorized modifications, and ensuring continuous security across both online and offline environments. For future enhancement, the framework can be extended to integrate machine learning-based predictive analytics for proactive anomaly detection, and adaptive network resource management can be incorporated to further optimize real-time response efficiency under varying operational loads.

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