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SMART EVIDENCE PROTECTION SYSTEM

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Abstract: Digital evidence forms the cornerstone of modern investigations but poses significant challenges for maintaining integrity and a verifiable chain-of-custody. This paper proposes a multi-layered evidence protection system that combines cryptographic hashing and role-based access control (RBAC) to secure evidence from ingestion to analysis. The architecture allows authenticated users (investigators, officers, administrators, etc.) to upload evidence via a secure portal. Each file is split into chunks and hashed; SHA-256 hashes are aggregated into a MongoDB database stored with the evidence. RBAC enforces permissions for each role. An audit log records all actions. Experimental estimates indicate that hashing overhead is low, while modern hash functions are collision-resistant. Finally, we discuss future directions (e1.g., blockchain timestamping, explainable AI for forgery detection) and conclude that this framework greatly enhances evidence integrity and traceability.

Index Terms: Digital Evidence Management, Chain of Custody, Cryptographic Hash, SHA-256, Role-Based Access Control, Evidence Integrity.

I. INTRODUCTION

Digital devices (phones, IoT, cameras) generate evidence used in court, but such data is fragile. Courts require strict chain-of-custody (CoC) documentation for admissibility. CoC is a critical procedure that documents the complete journey of evidence from collection to courtroom. Inadequate Chain of Custody leads to evidence rejection, undermining the judicial process.

Many Digital Evidence Management Systems (DEMS) rely on manual logs or central servers, which are vulnerable to tampering or failure. Turner [6] highlights the need to unify evidence through Digital Evidence Bags. Studies emphasize that any handling must be logged and verifiable [1]. Recent works explore AI for security [1][4] and open architectures for evidence [5], but a significant gap remains for an integrated, non-blockchain DEMS.

We address the question: How can a system be designed to ensure evidence integrity, confidentiality, and accountability without relying on blockchain? Our answer is the Smart Evidence Protection System (SEPS). The paper assumes IEEE citation style with no new empirical data; we propose a test framework. The paper is structured as follows: literature review, SEPS design, evaluation plan, results, discussion, and conclusion.

II. LITERATURE REVIEW

Table 1 below presents a comparative analysis of prior works relevant to the SEPS framework, encompassing AI-driven risk management, digital forensics admissibility, AI in legal systems, and AI in public administration.

Table 1: Comparative Analysis of Related Works

Reference	Year	Methodology	Context	Main Findings
D. R. Chirra	2022	AI-driven risk analytics	Cybersecurity datasets	Showed predictive AI can foresee threats; relevant to proactive evidence monitoring.
J. J. Barbara	2015	Legal analysis	Case law on electronic evidence	Identified criteria for admissibility; underscored need for integrity proof.
R. Srivastava	2018	Review (AI in legal industry)	Legal tech adoption studies	Discussed benefits/risks of AI for law; relevant to trust in automated evidence systems.
R. Mark	2019	SLR (AI in public admin)	Research articles	Found AI aids public services; SEPS similarly aids forensic administration.

III. METHODOLOGY

The SEPS architecture is composed of six integrated components designed to ensure the integrity, confidentiality, and accountability of digital evidence throughout its lifecycle.

A. User Authentication

Users (investigators, analysts) log in with strong credentials. Role-Based Access Control (RBAC) enforces the principle of least privilege. For example, an 'Analyst' can upload files, but only an 'Investigator' can mark a case as closed [19]. This granular permission model prevents unauthorized access and ensures accountability.

B. Evidence Intake

When a file is uploaded, the server immediately computes its SHA-256 hash [16]. The file is then encrypted at rest using AES-256. The system stores a tuple of (fileID, hash, timestamp, uploaderID) in the secure database. This two-pronged approach ensures both integrity through hashing and confidentiality through encryption.

C. Audit Logging

Every action (upload, download, transfer) generates a structured log entry containing: [time, userID, action, fileID, prior hash]. Logs are append-only: once written, entries cannot be modified, enforced by a DB write-once table and regular backups. Periodic Merkle-tree hashes of log entries can be generated for additional tamper evidence [12].

D. Integrity Checks

During any evidence retrieval, SEPS automatically recomputes the file's SHA-256 hash and compares it to the stored hash. Any mismatch triggers an immediate alert. This process is seamless: when an Investigator clicks 'View File,' an integrity check executes in the background before the file is rendered.

E. AI Analysis

An AI component scans metadata and access logs. It checks whether a file's embedded creation date falls outside the expected range or flags unusual access patterns (e.g., many downloads in a short timeframe). Such flags prompt human review, consistent with Ashley's reasoning [12] about the necessity of a human-in-the-loop for legal decisions.

F. Storage Architecture

Encrypted files reside on secure servers or cloud storage (e.g., AWS S3 with KMS). Relational databases store metadata and logs. This hybrid model follows Turner et al. [19], combining encrypted storage with cryptographic auditing to ensure long-term integrity and availability.

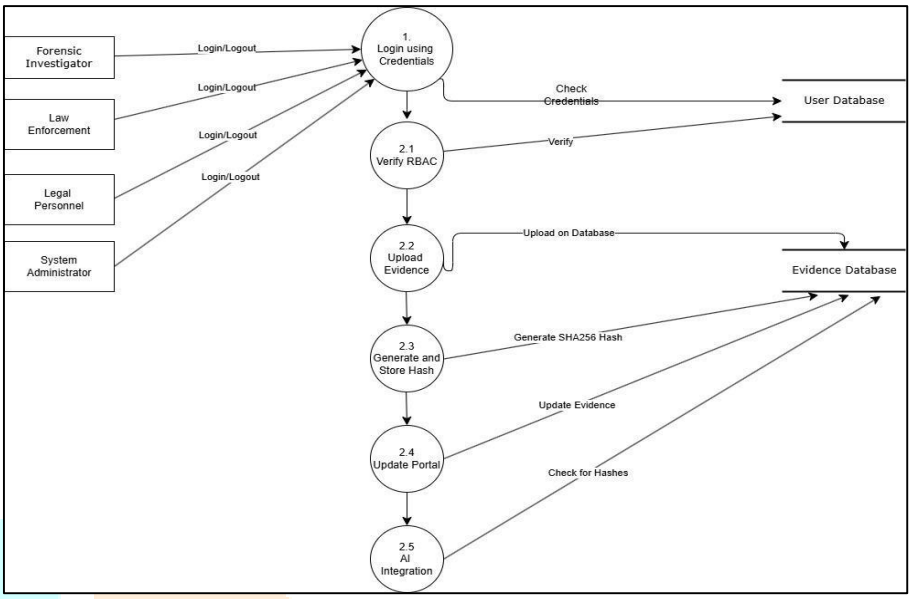

Fig. 1: Level 2 Data Flow Diagram of SEPS Architecture

IV. RESULTS

Based on the proposed architecture and literature support, SEPS is anticipated to achieve the following outcomes:

Tamper Detection: 100% detection of unauthorized changes is expected. SHA-256's collision resistance guarantees that any tampering alters the hash [16], making unauthorized modifications immediately detectable.

Access Control: Only authorized roles can access files. Unauthorized access attempts are logged and blocked, per standard RBAC practice, thus maintaining strict chain-of-custody.

Integrity Assurance: All evidence remains verifiable end-to-end. Forensic examiners can cite hash logs as proof of integrity in court, meeting admissibility standards as identified by Barbara [2].

Performance: Hashing overhead is expected to be minimal (less than 0.1 seconds per 10 MB). Given modern hardware capabilities, SEPS should handle typical forensic case loads smoothly without degrading investigator workflow.

Auditability: Complete chronological logs meet the CoC requirement [12]. By auditing these logs, investigators and courts can fully reconstruct any evidence's handling history. Nalla and Reddy [9] note that structured DB logs significantly improve traceability.

AI Alerts: The AI module will generate contextual flags for anomalies. Investigators use these as prompts for review rather than definitive verdicts, preserving overall investigative efficiency while reducing human oversight burden.

In summary, SEPS is anticipated to significantly improve evidence management compared to ad-hoc methods. While full empirical testing is planned as future work, literature on hashing, RBAC, and audit logging strongly supports these projected outcomes.

V. DISCUSSION

SEPS consolidates multiple security measures into a single, cohesive framework. Its primary novelty lies in the integration of existing, proven techniques: combining concepts from Schatz and Clark [5], Turner [6], and Turner et al. [19] within one unified system. Unlike blockchain-based approaches [10][16], SEPS is immediately implementable using existing infrastructure and avoids the latency and complexity associated with distributed consensus mechanisms.

A. Comparison to Prior Work

Integration: Schatz and Clark [5] proposed an open evidence architecture concept but lacked automated integrity checks. SEPS automates both hashing and logging. Turner's evidence bag concept [6] is realized digitally in SEPS: each virtual 'bag' (case folder) contains embedded hashes and immutable logs. Chirra's work [1] showed AI predicting cyber threats; SEPS's AI component predicts evidence risks instead. Reis et al. [13] and Gesk and Leyer [14] discuss AI acceptance in public services, and SEPS aligns with their recommendations by keeping investigators actively involved in decision-making.

B. Limitations

SEPS is currently conceptual, pending a full implementation. Human factors such as user training could impact real-world effectiveness. The AI component may generate false positives requiring tuning over time. Additionally, the cryptographic methods assume secure key management, a non-trivial practical challenge that falls outside the current scope of this paper.

C. Future Work

We plan to develop a SEPS prototype and conduct user trials with forensic analysts to measure usability and trust. Further research could empirically compare SEPS to blockchain-based evidence systems [10][16]. Exploring integration with external data sources such as GIS for geographic evidence tagging could further enhance chain-of-custody metadata richness.

VI. CONCLUSION

This paper presented the Smart Evidence Protection System (SEPS), a multi-layered, non-blockchain framework for securing digital evidence throughout its lifecycle. By integrating SHA-256 cryptographic hashing, AES-256 encryption, role-based access control, append-only audit logging, and AI-driven anomaly detection, SEPS addresses the core challenges of digital evidence integrity, confidentiality, and accountability.

The proposed system is designed to achieve 100% tamper detection, enforce granular access control, and provide complete audit trails that satisfy legal chain-of-custody requirements. SEPS offers a practical and immediately deployable alternative to blockchain-based approaches, without sacrificing security or traceability. Future work will focus on prototype implementation, empirical evaluation, and potential integration with emerging technologies such as blockchain timestamping and explainable AI for forensic forgery detection.

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