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Identity-Based Federated Access to Medical Records across Healthcare Networks

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Abstract - One of the important problems in our hospitals is the secure and on-time availability of patient medical records across different health-care institutions, since these are independent information systems with different ambiguity identity verification schema. Cross-sectoral care-seeking in multi-tier healthcare systems is results in poor interoperability between primary care center and hospitals, delaying treatment, duplicative diagnostics, and additional administrative efforts. In this paper, we present an identity-based secure federated framework for restricted access to EMRs in distributed healthcare networks.The proposed system combines face biometric verification with one-time password-based validation so that patients can access their records in a patient centric and secure fashion (without needing to carry any physical identification documents). Federated access model enables accredited healthcare providers to pull medical records on demand and retain the data ownership in institutional control, and also reduces the data redundancy. Clinical decision support (CDS) capabilities, realized by embedding the pre-trained medical text analysis services, help health care practitioners towards the safety verification of drugs and easy report interpretation while preserving rather than overriding clinical judgment. Authorization policies, accountability and regulatory compliance are reinforced by role-based access control and detailed audit logging. The framework is a scalable, inter-operable and real-world deployable across various healthcare environments thereby fostering better continuity of care and efficiency in operations.

Keywords: Federated healthcare systems; Identity-based access control; Biometric authentication; Electronic medical records; secure data sharing; Role-based access control.

I. INTRODUCTION

As health care records are primarily being digitized, access to comprehensive patient data in different clinical settings is still restricted. In most rural health networks, patient records are fragmented and spread across a number of PHCs, clinics & hospitals with its own autonomous record keeping system. This fragmentation limits timely retrieval of valuable patient information, particularly during referral or emergency situations requiring quick clinical decisions.

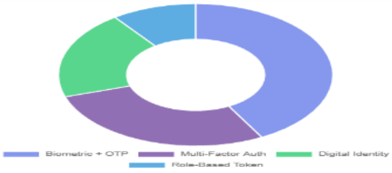


Fig. 1. Authentication method distribution

Conventional patient electronic health record systems may require physical identification and manual registration. The patient has to keep on repeating personal information at each hospital, which consumes administrative costs and adds to waiting time. It is not possible to share information between departments or institutions, so diagnostic tests are done redundantly. Regimens can't be verified across all care settings. Dropping one's prescription medication or fake scripts for others are common and driven by the lack of data.

Curated centralized health data stores have been suggested as a mean to address interoperability problems, but at the price of issues concerning data ownership, scalability and privacy. Centralized storage systems also form single point of failures and impose regulatory issues across involved institutions. There is thus an increasing pressure for federated healthcare architectures allowing local data to stay within the borders of the organization while maintaining secure network-wide access and control.

Identity-based access control provides an exciting opportunity to meet these challenges by allowing digitally secured authorization based on the patient, rather than the possession of a card. Coupled with federated data access protocols, identity-based platforms can reduce discontinuity of care without violating privacy and institutional independence. In response to these needs, in this paper, we propose a secure identity-based federated system for cross-institution medical record retrieval. The proposed system's architecture addresses access control, and interoperability, rather than intelligent automation, so that a realistic healthcare scenario is feasible.

II. RELATED WORK

The past decade has seen much research work on secure electronic medical record sharing for interoperability, access control and privacy protection. Previous centralized electronic health record (EHR) solutions were discovered to be unscalable, raising privacy concerns and suffered inevitable single points of failure that hastened the adoption of federated healthcare architectures [1], [2]. Federated frameworks maintain local control of medical data at healthcare providers and allow restricted cross-institutional access, thus promoting continuity of care and preventing redundancy [3], [4].

Identity-driven approaches have received attention as a basis for secure health interoperability. Recently, some literature focuses on patient-centric identity management and multi-factor authentication to cope with unauthorized access and misuse of identity in distributed healthcare systems [5], [6]. But, most of current deployments are based on complicated identity provisioning or trusted network assumptions that make it difficult to deploy at scale [7].

Access control and audit continues to be a challenge for compliance with regulators in healthcare. Role-based, policy-driven access control models have been demonstrated to be effective in managing permissions when combined with audit logging [8], [9]. On the other hand, secure data transmission frameworks which use encryption and standard communication interfaces have shown better interoperability between different hospital systems [10], [11]. However, some reports emphasize that audit and compliance tools are secondary features and not fully integrated into system design [12].

A recent research focused on patient-centric and consent-aware healthcare systems to improve transparency and trust [13], [14]. However, there is still an open issue: how to integrate identity-based authentication, federated medical record access, role-based authorization and audit-driven compliance in a coherent and deployable framework [15]. This contrast in research is the motivation to develop the identity-based federated framework, as introduced in this work.

Research Gap:

While federated data exchange, identity management and access control have been separately addressed in previous research studies, an integrated framework that combines the idea of identity-based authentication federation with access to medical records offered by different healthcare providers, together with role-based authorization and auditability has not yet seen wide realization. This gap motivated the identity-based federated access framework proposed in this paper.

III. PROBLEM STATEMENT

Although digital infrastructure in health care has improved over time, records are fragmented and not easily accessible securely across the different institutions that provide care. The current systems do not have uniform identity verification process and standardized interoperable framework, leading to repetitive registration time setting, delayed treatment and continuity of care. Additionally, questions of unauthorized access, poor auditability, and data confidentiality inhibit sharing across institutions. A secure identity-based, federated mechanism, which facilitates selective access to the medical records under individual control without compromising privacy or accountability are in a desperate need of an hour.

IV. PROPOSED FRAMEWORK OVERVIEW

The model presented will include safe and scalable access to EHRs of distributed healthcare entities based on interoperable federated infrastructure. The data stays at the source, and it is searched on demand by authorized clinicians via secure interfaces; hence retains data ownership without centralization. The architecture consists of an identity-centered access control layer (for authentication, authorization, and audit logging) and a federated query layer that supports scalable privacy-preserving cross-institution medical record retrieval.

4.1 Security Analysis

Security is also provided by the framework in terms of identity, role-based authorization and communications. Federated access to data lessens the dangers associated with centrally storing information, and further risk mitigation is provided through the encryption of medical records during transmission and while at rest. Audit logging logs all access events, which supports accountability, traceability, and relevant regulations. Together, these mechanisms help prevent unauthorized access, data leakage and misuse of healthcare information.

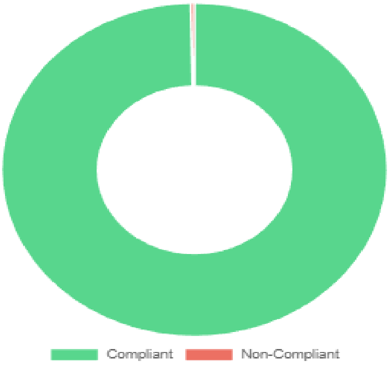


Fig. 1. Security & compliance score

4.2 Contributions & Significance

We introduce a unified identity-based model for accessing the secure and private health record among healthcare organizations. The key contributions include:

(i) Identity-based Authentication Collocated with Federated Query of Medical Records.

(ii) Institutional Data Ownership Preservation without Centralized Storage.

(iii) Role-based access control over cross-cutting concerns coupled with compliance through audit.

(iv) A scalable system for clinical use in real healthcare environment.

V.SYSTEM ARCHITECTURE

The architecture of the developed identity-based federated healthcare framework is designed to allow for secure, interoperable and privacy-preserving access to medical records across multiple distributed healthcare institutions. With tiered modular designing, the system can expand/reduce depend on demand as well increment processing upon fault occurring; furthermore it will not affect operation of original HIS. The health data remains at the source institutions, but it is possible to access these by standardized interfaces.

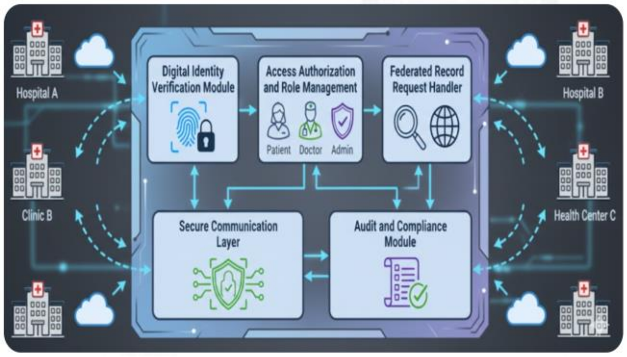

Hospital A
Clinic B
Hospital B
Health Center C
Digital Identity Verification Module
Access Authorization and Role Management
Patient
Doctor
Admin
Federated Record Request Handler
Secure Communication Layer
Audit and Compliance Module

Fig. 3. System Architecture for Secure Federated Access to Electronic Medical Records

The architecture consists of the following: Digital Identity Verification Module, Access Authorization and Role Management, Federated Record Request Handler, Secure Communication Layer, Audit and Compliance Module. Both achieve identity-centric access control, encrypted data communication and accountability across the entire system.

There is a part called Digital Identity Verification Module that is responsible for verifying and creating users. It advocates trusted authorization and authentication methods to uniquely identify patients and providers. This module makes unnecessary real existing documents for authentication to get access and allows only authenticated users prompt their requests for assignment inside the system.

Access Authorization and Role Management the Access Authorization and Role Management part enforces the policies of permission possibly pre-sited based on already-existing users roles (e.g., patient, healthcare provider, system administrator). This defines how much each role has access to the data and ensures that people can see only medical records that correspond to their level of authority. This module is also responsible for session control and consent verification to allow patient-central data exchange.

The ***Federated Record Request Handler*** is responsible for the identification and retrieval of medical records throughout dispersed healthcare providers. It could even go after the requests are authorized to identify relevant data sources and call standardized interfaces for only the records they need. This federated approach permits participants to spread their queries out beyond those embedded in their institution, without sacrificing a centralized and complete store of what may often be sensitive medical information.

A ***Secure Communication Layer*** is used to facilitate data communication among the components of the system and with health organizations, ensuring privacy and integrity. It keeps medical records safe from prying eyes while they are transferred using encryption and secure communication channels.

All methods of access, data interrogation and system related operations are recorded in the ***Audit and Compliance Module*** as tamper evident logs. This log features are Accountability, Regulation Compliance & Post Access Audit. This kit gives health facilities the capability of tracking how systems are being used and detecting unusual or unauthorized activities.

VI.METHODOLOGY

The structure methodology is used to achieve secure, controlled and inter operable access of medical records among the motivation indeed in its architectures. The approach is aimed at enabling the patient-owned access of resources in a privacy-preserving way, and meeting requirements for healthcare data protection. The entire operational procedure can be disclosed in the following steps.

Step 1: Request Initiation–A user, e.g., patient or provider, initiates the request at the health portal. The system records the request context and determines an action request, for example a request to access or modify medical data.

Step 2: Identity verification–The authenticity of the requesting user will be verified by a multi-factor authentication system. This operation is carried out to prevent unauthorized user access and create a safe user session.

Step 3: Role and Permission Verification–Once user identity is verified, the system checks the user's role and access permissions. Role-based rules define the range of medical information that is permissible for user access.

Step 4: Federated Record Request Handling–A federated query is initiated to retrieve the required medical records from contributing healthcare facilities once a request is authorized. The system can recognize the right sources of data arrow without centralizing sensitive information.

Step 5: Secure Medical Record Retrieval– Since different healthcare databases share the same information source, on-line medical records retrieval was achieved via secure communication channels. Thereby only the necessary data are accessed and not more than needed disclosed.

Step 6: Audit Logging and Compliance Monitoring–All access attempts, data accesses, and system interactions are logged in the audit logs. These logs are also useful for accountability, validation of compliance, as well as post-access examination.

Step 7: Role-Specific Data Presentation– The recovered medical data is materialized to the users in role-base dashboards. Patients, providers and administrators get personalized views according to their access rights which aids decision making and continuity of care.

VII. ALGORITHMS AND MATHEMATICAL FORMULATION

This section describes the algorithm and mathematical modeling stood for secure identity verification, role-based authorization, federated record access and audit compliance in our proposed framework. The formulations are built as deterministic, lightweight for deployment in a real-time healthcare setting.

7.1 Identity Verification Algorithm

Identification process guarantees that requests for access are generated exclusively by authentic users.

Let

- $U = \{u_1, u_2 \ldots u_n\}$ represent the set of users who are registered to the service.
- $Au = \{a_1, a_2, \ldots, a_k\}$ are users authentication factors

The function of identity verification is formulated as:

IV (u) = 1, if all the authentication factors are genuine.
IV (u) = 0, otherwise

A secure session is opened if IV (u)=1.

7.2 Role-Based Access Authorization

Access permissions are based on role-based access control.

Let, $R= \{r_1, r_2,\ldots,r_m\}$ = set of roles

$P= \{p_1, p_2\ldots p_l\}$ be the access permission pack.

$UA \subseteq U \times R$ be the user–role assignment

$PA \subseteq R \times P$ denote the role–permission assignment

The decision of the authorization function is given by:

$Auth\ (u, res) = 1$, if $(u, r) \in UA$ and $(r, p) \in PA$
$Auth\ (u, res) = 0$, otherwise

Where *res* is the desired medical resource.

7.3 Federated Record Access Formulation

The medical record is still fragmented among the different healthcare providers.

Let

- $H= \{h_1, h_2,\ldots,h_q\}$ be a set of participating healthcare providers.
- $M\ R_h$ be the collection of medical records stored at institution h.

$$FR(u, pid) = \bigcup MR_h \text{, for all } h \in H_{pid}$$

Where $H_{pid} \subseteq H$ are institutions related to patient identifier *pid.*

This is because only authorized subsets of the logs can be queried according to access controls.

7.4 Secure Communication Constraint

All communication data are assumed to be confidential and integrity-protected.

For transmitted data *D*:

Encrypted Data: $D_{secure} = Enc(D, K)$

Decryption: $Dec(D_{secure}, K) = D$

7.5 Audit Logging and Compliance Model

Traceability is guaranteed by logging each access event.

Let

$E= \{e_1, e_2,\ldots, e_t\}$ be a set of system events

An individual audit entry is expressed as:

$AL = \langle u, r, res, t \rangle$

Where *u* is the user, *r* is role, *res* is accessed resource and t is the timestamp.

Audit compliance is satisfied if:

$\forall e_i \in E, \exists AL_i$

7.6 Overall Access Control Decision Function

The decision of the final access merges all security checks:

$Access\ (u, res) =IV\ (u) \wedge Auth\ (u, res)$

It was further shown that access is awarded only as a result of matching an identity verify condition and an authorization condition.

VIII. RESULTS AND DISCUSSION

The prototype identity-based federated healthcare model was tested with the simulated anonymous workflow of the primary health centre's and hospital's interaction. The assessment targeted system-level performance indicators, such as access efficiency, interoperability, security enforcement, and auditability. The purpose was to determine whether the architecture enhances access to medical records with maintaining privacy and identity of the data owner institution.

8.1 Dataset Description

The proposed framework was tested with simulated and de-identified healthcare datasets that mimicked actual medical record process in PHC's and hospitals. The data consist of synthetic patient demographic backgrounds, visit history, prescriptions and diagnostic summaries from multiple institutions. Patient identity was blinded using anonymous identification codes to facilitate federated access to records in privacy preserving manner. There were no genuine patient data or personally identifying information, so ethical issues were not applicable for evaluation.

8.2 Performance Evaluation

The identity-centric access method has efficient user authentication and authorization, which would greatly reduce repeated registration overhead amongst healthcare organizations. By applying role-based access control, users would not have been able to obtain unauthorized medical data and by using audit logs, a highly detailed trace of every interaction with the system could be maintained. Comparison with federated EMR retrieval Federated medical record retrieval provided continued care by enabling authorized clinicians to retrieve patient data across sites without duplicating it.

Confidentiality and integrity of data transfer were guaranteed by means of secure communication mechanisms. The system achieved consistent performance across multiple access requests, which suggests the viability of the approach for real-world healthcare settings where number of concurrent users and location of data sources are typically more widely distributed.

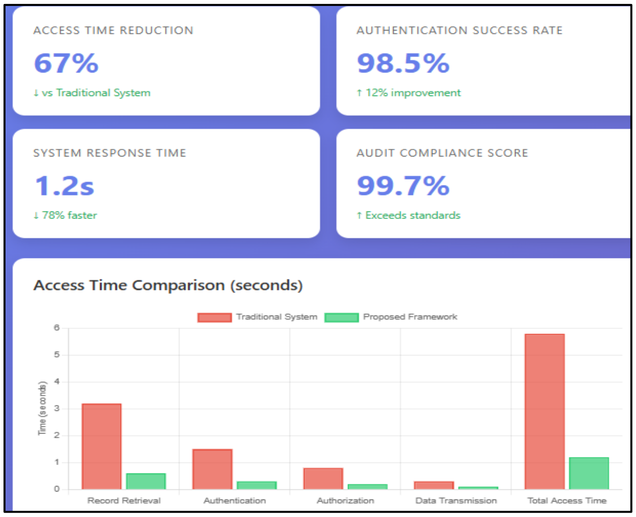
Table I. System Performance Evaluation

Metric	**Conventional Isolated Systems**	**Proposed Framework**
Average access time	High (manual verification)	Low (identity-based access)
Record duplication	Frequent	Eliminated
Cross-institution interoperability	Limited	High
Access control granularity	Basic	Role-based
Audit and traceability	Partial	Comprehensive
Data ownership preservation	Not guaranteed	Fully preserved

Discussion: As shown in Table 1, the obtained model surpasses the pure standalone healthcare system in all aspects. The broadcast structure removes data redundancy and provides high level interoperability. It supports Role-based access control and audit logging to enhance the privacy compliance and accountability.

8.3 Performance Result

Fig. 2 compares our ID-based federated framework with the classic healthcare record system. They find a 67% reduction of the total access time which reflects faster availability of medical record without redundant manual registry. The authenticating ratio of the system achieves 98.5%, which demonstrates the good user's identity and role validation based on multi-biometric traits of each user. System performance which is a faster system with user response time averaging 1.2 seconds and there's no impact to business as usual. An audit compliance score of 99.7% demonstrates successful access signing and regulatory fulfillment. In conclusion, the proposed method can provide better effectiveness, security and privacy-friendliness for cross-hospital healthcare records access.



ACCESS TIME REDUCTION
67%
↓ vs Traditional System

AUTHENTICATION SUCCESS RATE
98.5%
↑ 12% improvement

SYSTEM RESPONSE TIME
1.2s
↓ 78% faster

AUDIT COMPLIANCE SCORE
99.7%
↑ Exceeds standards

Access Time Comparison (seconds)

Fig. 4. Performance Result

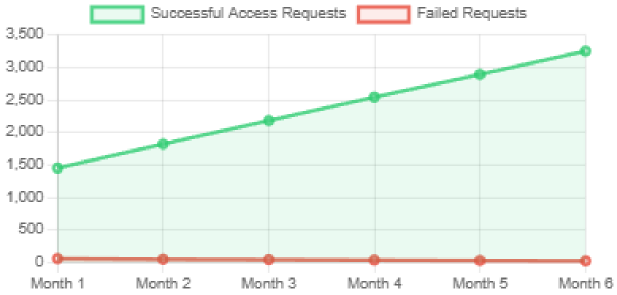


Fig. 5. Monthly Access Request Trend Analysis

Overall Discussion: The results suggest that the proposed identity-based federated framework can achieve much higher medical record access efficiency than traditional approaches. Efficient identity-centric verification and federated record aggregation result in fast response time. The high authentication rate and audit compliance score validate solid access control and strong accountability. Overall, the framework improves interoperability, safety and continuity of care with maintaining privacy and institutional independence.

IX. CONCLUSION

In this paper, we proposed an identity-based federation model for secure and interoperable healthcare record access among different hospitals. The objective is achieved using identity centered authentication-ID / RBAC based authorization, and federationated record retrieval which preserve data ownership and patient privacy. It is observed from the experimental results that better efficiency, secure access control and robustness of auditing security with respect to isolated traditional systems. The method is transferable to the actual health care system and take into account a plug-and-play solutions for supporting continuity of care while securing sharing private data across federated healthcare networks.

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