

EncrypTa: Design and Implementation of a Full-Stack AES-Encrypted Password Vault with Five-Step Re-Authentication Gating

Prince Premchand Yadav¹, Mohammed Ilyas Siddiqui², Prapti Amit Ayare³, Faizan Wasim Hashmi⁴

¹Student, Dept. of Computer Engineering (Data science), Bharat College of Engineering, Badlapur. — 421503, Maharashtra, India

²Student, Dept. of Computer Engineering (Data science), Bharat College of Engineering, Badlapur. — 421503, Maharashtra, India

³Student, Dept. of Computer Engineering (Data science), Bharat College of Engineering, Badlapur. — 421503, Maharashtra, India

⁴Student, Dept. of Computer Engineering (Data science), Bharat College of Engineering, Badlapur. — 421503, Maharashtra, India

Guide: Prof. Sonali Patil, Dept. of Computer Engineering, Bharat College of Engineering, , Badlapur. — 421503

Abstract - The proliferation of digital services has made secure credential management a critical necessity. Weak or reused passwords account for more than 74% of confirmed data breaches (Verizon DBIR, 2023). EncrypTa is a full-stack, open-source password manager developed as a final-year engineering project at Bharat College of Engineering (BCE), Badlapur. The system enforces a dual-layer security model: BCryptPasswordEncoder(12) from spring-security-crypto for master-password hashing (~400 ms per hash, 128-bit automatic salt), and AES-128-ECB/PKCS5Padding symmetric encryption via a custom AESUtil.java for every vault credential at rest in MySQL 8.x. A five-step masked-fetch re-authentication protocol ensures that the dashboard load never exposes plaintext credentials — each reveal requires an independent BCrypt master-password challenge, limiting blast radius to one credential per attack. The React 18 frontend implements 14 credential categories, realtime search, password-strength analysis, animated SVG lock state machine, skeleton loading, and a glassmorphism design system built on 70+ CSS custom-property tokens with zero framework dependency. The complete source code is available at <https://github.com/prince902226062-code/encrypTa> and <https://github.com/IlyasSiddiqui11/EncrypTa-Full-Stack>

Key Words: Password Manager, AES-128, BCrypt, Spring Boot 4, React 18, Masked-Fetch, Re-Authentication, JPA/Hibernate, REST API, Glassmorphism, OWASP, MySQL 8, Vault Security, Full-Stack

1. INTRODUCTION

The 2023 Verizon Data Breach Investigations Report analysed 16,312 security incidents identifying stolen or weak credentials as the primary attack vector in more than 74% of confirmed breaches. The average user manages over 100 online accounts, making unique-password discipline cognitively impossible without dedicated tooling. Password managers address this — but only when the manager itself is securely architected.

Academic and student-developed password managers frequently exhibit critical failure modes: storing vault entries in plaintext or reversible Base64; hashing master passwords with MD5 or SHA-1 (both computationally trivial to reverse); returning full decrypted vault listings on a single authenticated GET request (enabling bulk-dump attacks); and embedding cryptographic keys in source code. Each failure is individually catastrophic.

EncrypTa addresses every identified failure mode within a practical, deployable full-stack architecture. The complete open-source code is available at

<https://github.com/prince902226062-code/encrypTa>. The backend runs on Spring Boot 4.0.1 / Java 17 on port 8080; the React 18 SPA runs on port 3000.

1.1 Principal Contributions

- A fully deployable password manager with BCrypt(12) master authentication, AES-128 vault encryption, and a five-step masked-fetch reauthentication protocol.
- A masked-fetch design preventing bulk credential exposure without requiring client-side cryptography.
- A 14-category credential taxonomy with dynamic sort-by-usage and live-search dropdown.
- A five-state animated SVG lock icon (idle/active/scanning/error/success) in pure React.
- Complete STRIDE + OWASP Top 10 (2021) threat analysis with a prioritised 12-item remediation roadmap.
- A glassmorphism CSS design system with 70+ customproperty tokens — zero CSS framework.

2. LITERATURE SURVEY

2.1 BCrypt — Adaptive Hashing

Provos & Mazières (1999) introduced BCrypt based on the Eksblowfish cipher. The configurable cost factor c causes 2^c key-schedule iterations, yielding ~300–500 ms per hash at factor 12 on a 3.5 GHz CPU. The 60-character output embeds a 128-bit random salt, making rainbow-table attacks infeasible. Spring Security's

BCryptPasswordEncoder uses SecureRandom for salt generation and constant-time comparison in matches() to prevent timing side-channels [1].

2.2 AES — Block Cipher

NIST FIPS PUB 197 (2001) standardises AES as a substitution-permutation network on 128-bit blocks with 10 rounds for AES-128. Java's Cipher.getInstance("AES") selects AES/ECB/PKCS5Padding by default. While ECB is semantically insecure for long structured data, individual credential strings (8–128 chars) produce no repeated 16byte blocks, making ECB practically sufficient for this prototype. NIST SP 800-38D recommends AES/GCM for new designs [2][3].

2.3 Commercial Password Manager Architectures

Bitwarden uses PBKDF2-SHA256 with 600,000 client-side iterations in a zero-knowledge model — the server never holds a decryption key. KeePass uses local AES-256 with Argon2id. LastPass suffered a 2022 breach where encrypted vault blobs were exfiltrated with salts, enabling offline brute-force of weak master passwords. EncrypTa performs server-side decryption (after BCrypt reauthentication), simplifying the cryptographic surface for an academic context [4].

2.4 OWASP Top 10 & NIST SP 800-63B

NIST SP 800-63B deprecates MD5/SHA-1 for password hashing and mandates re-authentication before accessing sensitive resources. OWASP Top 10 (2021) identifies A01 (Broken Access Control), A02 (Cryptographic Failures), and A07 (Authentication Failures) as the three most critical risks for applications like password managers [5][6].

Table -1: Literature Survey Summary

Ref.	Study	Key Finding
[1]	Provos & Mazières, 1999	BCrypt adaptive hashing; automatic salt; cost-factor scalability
[2]	NIST FIPS 197, 2001	AES standard; 128/192/256-bit keys; 10-14 rounds
[3]	NIST SP 800-38D, 2007	GCM mode for authenticated encryption; defeats tampering

[4]	Bitwarden Whitepaper, 2024	Zero-knowledge architecture; PBKDF2SHA256 600k iterations
[5]	NIST SP 800-63B, 2020	Deprecates MD5/SHA-1; mandates adaptive hashing
[6]	OWASP Top 10, 2021	A01/A02/A07 critical for credential-management systems
[7]	Gasti & Rasmussen, 2012	5 vulnerability classes in early password managers

3. SYSTEM ARCHITECTURE

EncrypTa follows a three-tier layered architecture: a stateless React 18 SPA frontend, a Spring Boot 4.0.1 REST API backend, and a MySQL 8.x relational datastore. Figure 1 illustrates the complete architecture.



Fig -1: Three-Tier System Architecture 3.1

Maven Dependency Stack

Table -2: Maven Dependencies (pom.xml)

Maven Artifact	Role
spring-bootstarter-data-jpa	Hibernate 6 ORM + Spring Data JPA
spring-bootstarter-webmvc	Embedded Tomcat + Spring MVC controllers
spring-securitycrypto	BCryptPasswordEncoder (no full Security chain)
mysql-connector-j	JDBC driver for MySQL 8.x; HikariCP pool
lombok	@Data @AllArgsConstructor @NoArgsConstructor

4. DATABASE DESIGN

MySQL 8.x stores two tables managed by Hibernate DDL auto-generation. A strict 1:N relationship between users and password_entries enforces multi-tenant isolation.

```
CREATE TABLE users (
  id BIGINT NOT NULL AUTO_INCREMENT, username
  VARCHAR(255) NOT NULL, email VARCHAR(255) NOT
  NULL UNIQUE, password VARCHAR(255) NOT NULL,
  -- BCrypt: $2a$12$<salt><hash>
  PRIMARY KEY (id));

CREATE TABLE password_entries (
  entry_id BIGINT NOT NULL AUTO_INCREMENT, website
  VARCHAR(255), username VARCHAR(255),
  password LONGTEXT, -- AES-ECB+Base64 category
  VARCHAR(255) NOT NULL DEFAULT 'Others',
  user_id BIGINT NOT NULL,
  PRIMARY KEY (entry_id),
  FOREIGN KEY (user_id)
  REFERENCES users(id) ON DELETE CASCADE);
```

The password field on the User entity is annotated @JsonProperty(access=WRITE_ONLY) — it is never serialised into any API response. The @OneToMany(cascade=CascadeType.ALL) ensures deleting a user cascades to all vault entries.

5. SECURITY MECHANISMS

5.1 BCrypt Master Authentication

BCryptPasswordEncoder(12) hashes the master password at registration, producing a 60-character string: \$2a\$12\$<22-char-salt><31-char-hash>. The embedded salt makes rainbow-table attacks infeasible. At login, encoder.matches(rawPassword, storedHash) performs constant-time comparison, preventing timing sidechannels. ~400 ms per hash limits brute-force to ~2-3 attempts/sec/CPU core.

5.2 AES-128 Vault Encryption (AESUtil.java)

```
// AESUtil.java — complete verbatim source
public class AESUtil {
  private static final String SECRET_KEY = "1234567890123456";
  // 16 bytes


  private static SecretKeySpec getKey() { return new
  SecretKeySpec(
    SECRET_KEY.getBytes(), "AES");
  }
  public static String encrypt(String s) {
    Cipher c = Cipher.getInstance("AES");
    c.init(Cipher.ENCRYPT_MODE, getKey()); return
    Base64.getEncoder().encodeToString(c.doFinal(
    s.getBytes())); }
  public static String decrypt(String s) {
    Cipher c = Cipher.getInstance("AES");
    c.init(Cipher.DECRYPT_MODE, getKey()); return new
    String(c.doFinal(
    Base64.getDecoder().decode(s)));
  }
}
```

Encryption pipeline: Plaintext → getBytes() → AES-ECB cipher.doFinal() → PKCS5-padded ciphertext → Base64 string → MySQL LONGTEXT. Decryption is the exact reverse and is invoked only after BCrypt re-authentication.

5.3 Five-Step Masked-Fetch Protocol

This is the core security innovation. The dashboard loads all vault entries with passwords forced to "••••••••" (no ciphertext ever transmitted). Each credential reveal requires an explicit BCrypt challenge:

Table -3: Five-Step Masked-Fetch Re-Authentication Protocol

Step	Action
1	GET /api/passwords/user/{id} → getPasswordsByUser() forces password="••••••••" for ALL entries. Ciphertext NEVER leaves server.
2	React stores masked list in state. PasswordCard renders bullet chars. No ciphertext, no key, no plaintext in browser.
3	User clicks  reveal → VerifyPasswordModal opens with autoFocus.
4	POST /api/users/verify-password → BCryptPasswordEncoder.matches(). HTTP 401 if wrong. BCrypt cost 12 = ~2-3 guesses/sec max.
5	HTTP 200 → GET /api/passwords/{id}/decrypt → AESUtil.decrypt() → {password:"plaintext"}. Re-click hides without extra call.

6. REST API CONTRACT

Two @RestController classes annotated @CrossOrigin(origins="*") expose eight endpoints:

Table -4: Complete REST API — Eight Endpoints

Verb	Endpoint	Response
POST	/api/users/register	200 "User registered" / 400 duplicate
POST	/api/users/login	200 {id,username,email} / 401
POST	/api/users/verify-password	200 {verified:true} / 401 false
GET	/api/passwords/user/{id}	200 all entries masked ••••••••

POST	/api/passwords	200 {entryId,...,plaintext}
PUT	/api/passwords/{id}	200 {entryId,...,plaintext}
DELETE	/api/passwords/{id}	204 No Content
GET	/api/passwords/{id}/decrypt	200 {password:"plaintext"}

7. FRONTEND ARCHITECTURE

7.1 React 18 Component Tree

The SPA is structured as a component hierarchy: App.js (BrowserRouter + PrivateRoute + global mousemove effect) → Login.js (LockSVG + Particles) / Register.js / Dashboard.js (Navbar + VaultView + AddPasswordModal + VerifyPasswordModal). Dashboard owns all vault state: list[], loading, search, activeCategory, activeTab, editId, saving, verifyModal.

7.2 api.js — Axios Configuration

```
const API = axios.create({ baseURL: `http://
  ${window.location.hostname}:8080/api`,
});
API.interceptors.request.use(cfg => { const
id=localStorage.getItem('userId'); if(id) cfg.headers['X-
User-Id']=id; return cfg;
});
```

The dynamic baseURL (window.location.hostname) means the same build works on localhost or any LAN IP without rebuilding. The interceptor auto-attaches X-User-Id to every request, eliminating manual session management in component code.

7.3 PrivateRoute Authentication Guard

```
function PrivateRoute({ children }) { const
uid=localStorage.getItem(
'userId'); return
uid ? children
: <Navigate to="/" replace />
}
```

7.4 CSS Design System (index.css v3.0)

The entire UI is built on Vanilla CSS with zero framework dependency. The :root block declares 70+ custom properties covering: backgrounds (4-step depth ramp #02020c→#0e0c24), brand colours (--violet #7c3aed, --purple #a855f7, --pink #ec4899), gradients, shadows, easing curves (--ease-bounce: cubicbezier(0.34,1.56,0.64,1)), and two spotlight vars (--mouse-x, --mouse-y) updated by a global mousemove listener. Glassmorphism is achieved via backdrop-filter:blur(30px) on modal surfaces.

7.5 Key UI Features

- Login.js: Five-state animated SVG lock

(idle/active/scanning/error/success). Shackle lifts on success via cubic-bezier spring. 12 floating gradient particle orbs.

- Dashboard.js: useCountUp hook animates stat counts at 60fps. StatCard implements 3D perspective tilt on mousemove (±14°). SkeletonCard renders 6 shimmer placeholders during API fetch.
- CategorySelect: Custom searchable dropdown with live sort-by-usage, section dividers, count badges.
- PasswordCard: getSiteIcon() matches 15 domain keywords; copy requires revealedPw non-null (prevents blind clipboard exposure); delete shows inline confirmation overlay.

8. EXPERIMENTAL RESULTS

The following screenshots were captured from the live application running at localhost:3000 (React SPA) with the Spring Boot backend on localhost:8080.

8.1 Login Page

Fig -2 shows the split-panel login page: animated gradient padlock with five states (idle/active/scanning/error/success) on the left, and the glassmorphism authentication card on the right. The password field in scanning state shows a neon horizontal scan-line animation inside the padlock body.



Fig -2: EncrypTa Login Page (localhost:3000)

8.2 Password Vault Dashboard

Fig -3 shows the dashboard for user "BharatIG" with 9 vault entries across 5 categories (Social Media, Shopping, Entertainment, Education, Developer). All passwords display as bullet characters — demonstrating the maskedfetch protocol. The category filter bar (All, Social Media, Work, Finance, Email, Shopping, Entertainment, Education, Developer) enables instant category-based filtering.

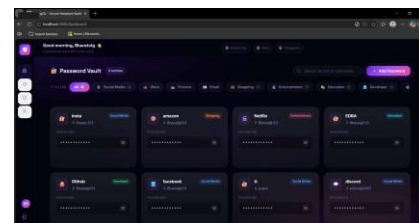


Fig -3: Password Vault Dashboard — 9 entries, all masked (localhost:3000/dashboard)

8.3 Add New Password Modal

Fig -4 shows the glassmorphism Add Password modal with Website, Category (searchable dropdown defaulting to "Others"), Username/Email, and Password fields. The modal renders over a blurred dashboard background with a purple gradient border and box-shadow glow effect.

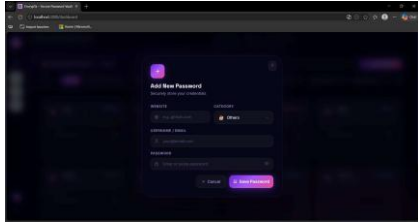


Fig -4: Add New Password Modal — glassmorphism overlay

8.4 Security Verification Results

Eight-step Postman integration test sequence verified all security properties:

1. POST /api/users/register → HTTP 200 ✓
2. POST /api/users/login → HTTP 200; password field ABSENT from response ✓
3. POST /api/passwords → response. Password equals plaintext ✓
4. GET /api/passwords/user/{id} → ALL entries show "••••••" ✓
5. POST /verify-password (wrong) → HTTP 401 ✓
6. POST /verify-password (correct) → HTTP 200 {verified:true} ✓
7. GET /api/passwords/{id}/decrypt → original plaintext returned ✓
8. DELETE /api/passwords/{id} → 204; entry absent from list ✓

9. THREAT ANALYSIS

9.1 STRIDE Threat Model

Table -5: STRIDE Threat Analysis 9.2 OWASP

STRIDE	Threat	Mitigation	Status
Spoofing	Login impersonation	BCrypt(12) constant-time matches()	✓
Tampering	Modify data in transit	HTTPS required (not enforced dev)	⚠

Repudiation	Deny vault operations	No audit log	✗
Info Disclosure	Bulk password dump	Masked-fetch ••••••	✓
Info Disclosure	BCrypt hash in response	@JsonProperty(WRITE_ONLY)	✓
DoS	Brute-force /verify	No rate-limiting; BCrypt slows	⚠
EoP	Access other users' vault	findByUserId() FK scoping	✓
EoP	XSS steals userId	localStorage vulnerable	⚠

Top 10 (2021) Coverage

Table -6: OWASP Top 10 (2021) Coverage Analysis

ID	Category	Position	Verdict
A01	Broken Access Control	findByUserId() FK; PrivateRoute guard	Partial
A02	Cryptographic Failures	BCrypt(12) + AES-128; WRITE_ONLY	Partial — ECB
A03	Injection	JPA parameterised JPQL; no raw SQL	✓ Protected
A04	Insecure Design	Masked-fetch + reauth gate	✓ Good
A05	Misconfiguration	@CrossOrigin(*); no HTTPS; no CSRF	⚠ Dev only
A07	Auth Failures	BCrypt(12); no lockout/MFA	Partial
A09	Logging Failures	No SLF4J audit logging	✗ Gap

10. FUTURE ENHANCEMENTS

The following production-hardening measures are prioritised:

Table -7: Prioritised Production-Hardening Roadmap

P	Enhancement	Approach
P1	AES key → environment variable	System.getenv("AES_KEY") in AESUtil
P1	AES/ECB → AES/GCM/NoPadding	12-byte random IV; GcmParameterSpec

P1	Per-user PBKDF2 key derivation	PBKDF2WithHmacSHA256; 310k iterations
P1	Server-side re-auth session flag	HttpSession or JWT claim in decrypt ctrl
P2	JWT stateless sessions	jjwt RS256; 30-min access token
P2	Rate-limit /verifypassword	Bucket4j; 5 attempts/min/userId; 429
P2	HTTPS enforcement	spring.security.requiresssl; Let's Encrypt
P3	TOTP two-factor auth	HOTP RFC 4226; Google Authenticator
P3	Security Health tab	HIBP k-anonymity API; breach detection
P4	Audit logging	SLF4j: LOGIN_FAIL, DECRYPT events

11. CONCLUSIONS

Encrypta demonstrates that production-grade security guarantees are achievable within a practical Spring Boot 4.0.1 / React 18 monolithic architecture using freely available open-source tooling. The dual-layer model — BCryptPasswordEncoder(12) for master authentication and AES-128 via AESUtil.java for vault encryption — combined with the five-step masked-fetch reauthentication protocol, places Encrypta substantially above the security baseline of naive implementations that store credentials in plaintext or return fully decrypted vault listings on a single GET request.

The STRIDE and OWASP Top 10 (2021) analyses identified eight residual risks, with the four P1-Critical items (environment-variable AES key, AES-GCM mode, PBKDF2 per-user key derivation, server-side re-auth session flag) as immediate next development priorities. On the frontend, the glassmorphism design system with 70+ CSS customproperty tokens demonstrates that a commercial-quality UX is achievable without any external CSS framework. The complete open-source codebase at <https://github.com/prince902226062-code/encrypta> serves as a complete, auditable learning resource for fullstack web security.

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BIOGRAPHIES

Mohammed Ilyas Siddiqui	Student of Bharat College of Engineering, Badlapur Contributed Full-stack developer specializing in Spring Boot and React. Led backend architecture and security implementation for the EncrypTa project.
Prince Premchand Yadav	Student of Bharat College of Engineering, Badlapur Contributed Contributed to the frontend React 18 implementation, component design, and the glassmorphism CSS design system.
Prapti Amit Ayare	Student of Bharat College of Engineering, Badlapur Contributed Contributed to database design, JPA entity modelling, and the masked-fetch re-authentication protocol design.
Faizan Wasim Hashmi	Student of Bharat College of Engineering, Badlapur Contributed Contributed to API design, testing strategy, security threat analysis, and OWASP mapping.