Abstract

Secure digital payments require authentication mechanisms that can resist modern threats such as impersonation, replay attacks, and OTP interception. Traditional OTP-based verification remains vulnerable to phishing and SIM-swap exploits, especially in high-value B2B transactions. This project presents *AuthoSec*, a Dual-QR Secure Payment System that introduces a multi-stage verification process combining encrypted QR exchanges with OTP validation. The system uses QR1 for transaction initiation and QR2 for counterparty confirmation, ensuring both parties participate in a tamper-proof handshake before OTP issuance. Built using Next.js, PostgreSQL, Firebase Authentication, React, and React Native (Expo), the platform integrates AES encryption, role-based access control, audit logging, and structured transaction states. The dual-QR approach significantly enhances integrity, non-repudiation, and protection against spoofing and replay attacks compared to conventional 2FA. AuthoSec demonstrates a practical, secure, and scalable framework for enterprise digital payments.

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1. Introduction

Digital payment systems have transformed modern financial ecosystems by enabling faster, more convenient, and globally accessible transactions. However, as business-to-business (B2B) payment infrastructures grow increasingly interconnected, the threat landscape has expanded significantly. Organizations now face persistent security challenges such as unauthorized access, identity spoofing, replay attacks, SIM-swap fraud, phishing, and malware-based credential theft [1]. Existing authentication models—primarily password-based login, SMS-based one-time passwords (OTPs), and basic two-factor authentication (2FA)—remain highly vulnerable to these sophisticated attack vectors.

Recent research highlights that authentication failures are among the leading causes of financial security breaches across digital platforms [2]. Studies on blockchain-based authentication, decentralized identity frameworks, and honeytoken-based intrusion detection show clear advancements but also reveal gaps. Many solutions rely heavily on centralized verification, introduce performance overheads, or lack practicality for real-world B2B workflows [3]. These limitations emphasize the need for a security mechanism that is both robust and operationally efficient.

1.1 Motivation

Despite improvements in cryptographic protocols and identity management, financial fraud continues to rise due to weaknesses in traditional OTP-based systems. Attackers can intercept or socially engineer OTPs, exploit replay vulnerabilities, or manipulate single-step verification processes. B2B transactions, which often involve higher financial value and multiple stakeholders, require stronger mutual authentication and end-to-end verification.

The motivation behind this project is to design a security model that ensures:

- Stronger identity binding between sender and receiver
- Tamper-resistant transaction flows
- Protection against replay and impersonation attacks
- Practical usability for real business environments

This leads to the development of **AuthoSec**, a Dual-QR Secure Payment System.

1.2 Problem Statement

Traditional OTP-based and password-driven authentication systems do not provide adequate protection against modern cyber threats in B2B transactions. These systems are susceptible to:

- OTP interception through SIM-swap or interception attacks
- Replay attacks using captured QR or session data
- Impersonation through phishing or spoofed identities
- Lack of mutual authentication between involved parties
- Weak audit trails and poor non-repudiation guarantees

There is a need for a **multi-layered, tamper-resistant, and mutually verifiable transaction mechanism** that ensures high-assurance authentication while maintaining practical performance and usability.

1.3 Objectives

The primary objectives of this project are:

1. To design a secure B2B payment verification model using **Dual QR-based authentication**.
2. To develop a tamper-resistant transaction workflow incorporating encrypted metadata, OTP validation, and audit logging.

3. To ensure mutual authentication between sender and receiver during all transaction stages.
4. To implement a multi-platform system including a **backend API**, **mobile application**, and **web interface**.
5. To evaluate the system's security performance against common threats such as replay, spoofing, and MITM attacks.
6. To provide a scalable and user-friendly interface suitable for real business environments.

1.4 Scope of the Project

The project focuses on building a production-ready secure payment verification system with:

- Dual-QR verification for transaction initiation and confirmation
- OTP-based final consent
- AES-encrypted QR payloads
- Firebase-based identity authentication
- Supabase/PostgreSQL database
- Web and mobile application interfaces
- Transaction logs, audit tracking, and notifications

Out of scope:

- Actual monetary settlement or financial institution integration
- Blockchain-based transaction storage (future scope)
- Hardware-based identity mechanisms like biometrics or smart cards

2. Literature Review

Secure authentication remains a critical component of modern digital payment ecosystems, particularly in high-value business-to-business (B2B) environments. Numerous studies have examined multi-factor authentication (MFA), QR-based verification, decentralized identity systems, blockchain-driven models, and intrusion detection mechanisms. This chapter reviews key research contributions relevant to the design of a secure dual-verification payment system and highlights the gaps that motivate the development of AuthoSec.

2.1 Blockchain-Based Authentication Models

Blockchain technology has been widely adopted to enhance authentication and transaction integrity due to its immutability and decentralized consensus. Studies such as [1] propose blockchain-backed identity frameworks that ensure tamper resistance and prevent unauthorized credential manipulation. Other works [2], [3] integrate smart contracts for multi-party transaction validation and secure event logging.

However, blockchain-based models often introduce significant computational overhead, latency, and deployment complexity, making them unsuitable for real-time, low-latency B2B payment workflows. Additionally, the requirement of full-node synchronization and distributed consensus increases operational costs and limits scalability in practical enterprise environments.

2.2 Honeytoken-Based Intrusion and Authentication

Honeytoken-based systems aim to detect unauthorized access by embedding decoy credentials or tokens within authentication workflows. Research such as [4] shows that honeytokens can effectively detect insider attacks, credential tampering, and unauthorized session hijacking.

While promising, honeytoken strategies must be combined with strong identity verification layers. They function primarily as *intrusion detection* rather than

prevention, and therefore cannot serve as a standalone mechanism for securing financial transactions.

2.3 Multi-Factor Authentication and QR-Based Mechanisms

Multi-factor authentication (MFA) techniques—such as SMS OTPs, authenticator apps, and device bound tokens—have been evaluated extensively in works like [5] and [6]. Despite improving security over password-only systems, they remain vulnerable to phishing, SIM-swap fraud, replay attacks, and malware interception.

QR-based mechanisms have also gained attention for device pairing, access control, and offline authentication. Studies like [7] propose encrypted QR codes for secure message exchange, while [8] analyze attack surfaces such as QR spoofing and static QR replacement. However, existing studies generally rely on *single QR-based verification*, which does not provide mutual authentication between two parties involved in a transaction.

2.4 Offline and Decentralized Transaction Systems

Offline-capable payment systems, including secure mobile wallets and hardware-based authentication, have been explored in works such as [9] and [10]. These models emphasize secure key storage, resilient validation workflows, and tamper-proof state tracking.

While offline-capable systems offer strong security guarantees, they are often hardware-dependent or constrained by device capabilities. They do not address the need for dual verification between sender and receiver in real-time transaction workflows.

2.5 Comparison of Reviewed Methods

Study Area	Security Strength	Weaknesses	Suitable for B2B Payments?
Blockchain-based authentication	High integrity, tamper-resistance	High latency, complex deployment, costly	❌ Not ideal
Honeytoken-based detection	Detects unauthorized access	Reactive, not preventive	⚠ Partial
OTP-based MFA	Easy to use, common	SIM-swap, phishing, replay attacks	❌ Weak
QR-based authentication	Simple, device-friendly	Vulnerable if single-step	⚠ Needs enhancement
Offline secure wallets	Strong cryptographic security	Hardware limitations, not dual-party	⚠ Limited

2.6 Research Gap

Based on the reviewed studies, the following gaps are clearly identified:

1. **Lack of Dual-Sided Verification:**
   Existing QR-based or OTP workflows rarely authenticate *both* sender and receiver simultaneously, leading to vulnerabilities such as impersonation and replay attacks.

2. **Single-Point Authentication Dependency:**
   OTP or password-based systems rely on a single step of verification, making them vulnerable to interception, manipulation, or spoofing.

3. **High Overhead in Decentralized Models:**
   Blockchain-driven systems provide strong integrity but are impractical for low-latency, high-volume enterprise payment flows due to complexity and performance constraints.

4. **Insufficient Mutual Authentication Mechanisms:**
   Most studies focus on unilateral authentication (verifying a user) rather than *verifying both users involved in a transaction*.

5. **Lack of Tamper-Resistant Transaction Sessions:**
   Research rarely combines encrypted QR codes, OTP verification, logging, and device-level authentication into a unified model.

2.7 Conclusion of Literature Review

The literature shows substantial progress in authentication technologies, yet none of the surveyed approaches fully meet the requirements of secure, real-time B2B transaction verification—particularly regarding dual-sided authentication, tamper-resistant session binding, and usability.

These gaps justify the development of **AuthoSec**, which integrates dual encrypted QR verification, mutual authentication, OTP consent, secure logging, and cross-platform interoperability as a comprehensive solution for secure enterprise payment workflows.

3. Methodology

The methodology adopted in this project follows a structured, iterative approach that emphasizes secure system design, multi-layered verification, and practical implementation. The goal is to develop a dual-QR secure payment system that ensures mutual authentication, tamper resistance, and high assurance during B2B financial transactions. This chapter explains the overall methodological framework used for application development, algorithm design, security enforcement, and system validation.

3.1 Methodological Approach

The project follows a **hybrid development methodology** combining elements of the Software Development Life Cycle (SDLC), security-oriented system design principles, and iterative testing. The development process was divided into conceptual design, algorithm formulation, system implementation, and performance evaluation.

The methodology emphasizes early identification of security risks, iterative refinement of transaction workflows, and integration of cryptographic safeguards at every stage. This ensures that the final system not only meets functional requirements but also demonstrates strong resilience against common attack vectors.

3.2 System Development Process

The development process consisted of four primary phases:

1. Requirement Analysis

Functional requirements were identified, including dual QR verification, encrypted payload handling, OTP-based consent, transaction logging, and mutual authentication. Non-functional requirements such as usability, low latency, scalability, and cross-platform support were also defined.

2. System Design

Architectural components—including the backend API, database schema, mobile application, and web client—were designed based on modular, service-oriented principles. The transaction flow was mapped out to clearly define each verification stage.

3. Implementation

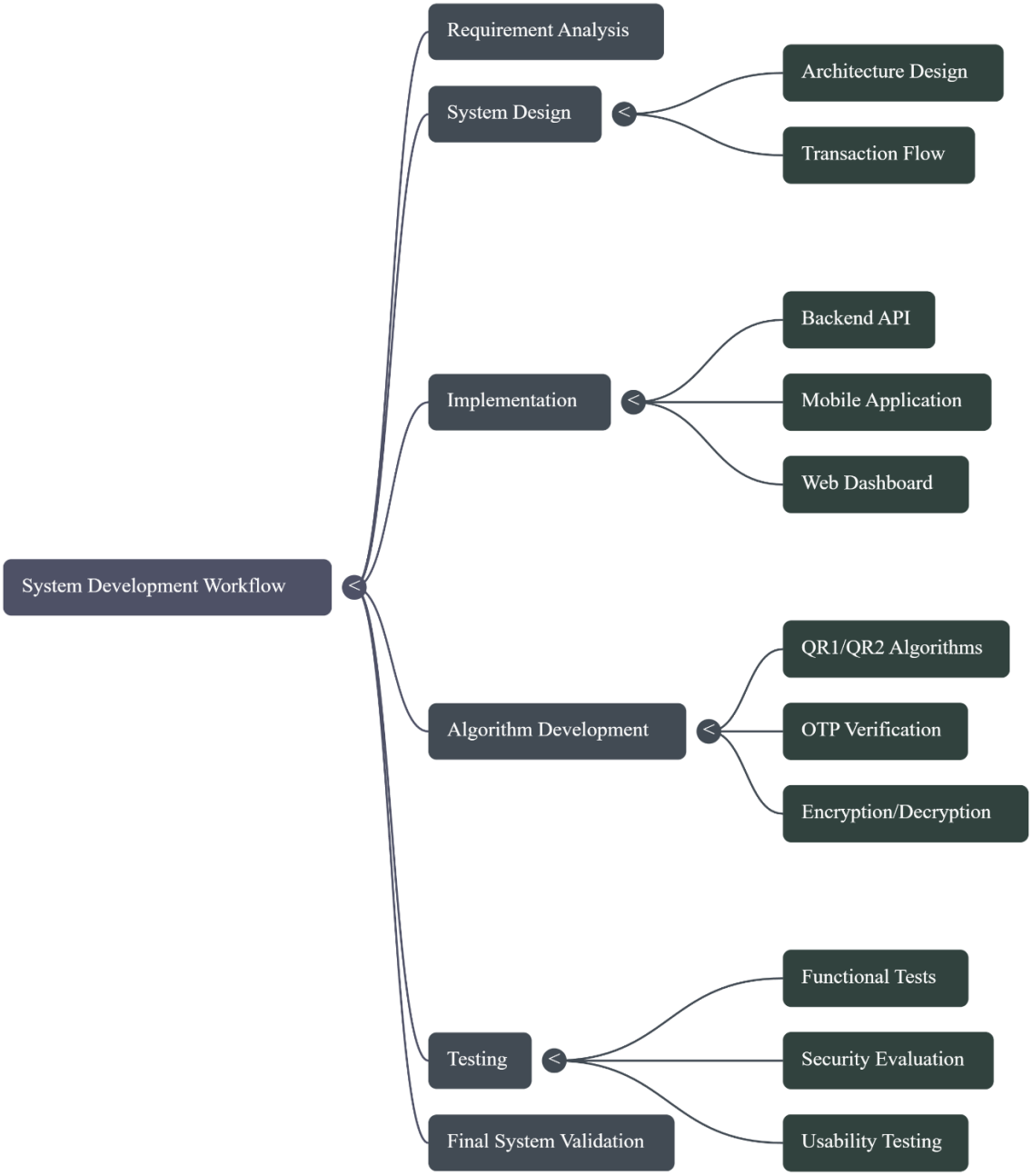
The system was implemented using modern technologies such as Next.js, React Native, PostgreSQL, Firebase Authentication, and Prisma ORM. Algorithms for QR generation, encrypted data exchange, OTP verification, and session management were coded following secure software engineering guidelines.

4. Evaluation & Testing

Security testing, functional testing, and usability assessments were conducted to validate system behavior under real-world conditions. Threat modeling was performed to ensure robustness against attacks such as replay, spoofing, MITM, and OTP interception.

3.3 Methodology Flow Diagram

Below is a plain-text flow diagram suitable for an academic report:


System Development Workflow
Requirement Analysis
System Design
Architecture Design
Transaction Flow
Implementation
Backend API
Mobile Application
Web Dashboard
Algorithm Development
QR1/QR2 Algorithms
OTP Verification
Encryption/Decryption
Testing
Functional Tests
Security Evaluation
Usability Testing
Final System Validation

3.4 Authentication Methodology

The authentication methodology integrates Firebase Authentication with custom OTP verification. Users authenticate through a two-step process: first via phone number or email using Firebase, and then through secure OTP verification linked to the transaction session. This layered approach ensures that identities are validated before any financial action is initiated.

OTP generation uses time-bound cryptographic hashing to prevent prediction or reuse. Firebase tokens are validated in all API interactions, ensuring that unauthorized clients cannot access protected endpoints.

3.5 Dual QR-Based Verification Methodology

The dual-QR system forms the core of the authentication workflow. The methodology consists of:

- **QR1 (Initiation QR)**: Generated by the sender to embed encrypted transaction metadata.
- **QR2 (Confirmation QR)**: Generated by the receiver after QR1 validation to ensure mutual authentication.

Each QR code contains encrypted fields such as transaction ID, participants, timestamps, and nonces. The methodology ensures that each QR is single-use, time-bound, and verified before the next step proceeds.

3.6 OTP Verification Methodology

After both parties validate QR1 and QR2, the sender requests an OTP to finalize the transaction. The OTP methodology ensures:

- One-time use

- Short validity (60–90 seconds)
- Cryptographic hashing during storage
- Attempt limits to prevent brute force

The OTP provides final consent from the legitimate account holder, completing the authentication chain.

3.7 Cryptographic Methodology

AES-GCM encryption is used to protect QR payloads due to its authenticated encryption properties, which provide:

- Confidentiality
- Integrity
- Tamper detection

Each transaction uses a unique key and IV to prevent replay attacks. Cryptographic modules follow NIST-recommended practices, and sensitive data is never stored in plaintext.

3.8 Justification of Methods

The methods used in this project were chosen for the following reasons:

- **Dual QR Verification** ensures mutual authentication, eliminating impersonation attacks common in single-step QR systems.
- **AES-GCM encryption** provides strong integrity verification and prevents payload tampering.
- **Firebase Authentication** offers reliable identity verification and reduced infrastructure overhead.

- **Next.js Backend Architecture** supports fast serverless execution and scalable API endpoints.
- **React Native Mobile Framework** ensures cross-platform deployment without compromising security APIs.
- **Prisma + PostgreSQL** provides a type-safe ORM and stable relational data model suitable for transaction logging.

These choices optimally balance performance, security, scalability, and developer productivity.

3.9 Testing Methodology

A structured testing approach was used to validate the system:

1. Functional Testing

Each component—including QR generation, QR scanning, OTP verification, and logging—was tested individually and as part of the complete flow. Boundary conditions such as expired QR codes, invalid OTPs, and mismatched transaction states were evaluated.

2. Security Testing

Attack simulations were performed to evaluate the system against:

- Replay attacks
- QR spoofing
- MITM attacks
- Brute-force OTP attempts
- Token tampering

All vulnerabilities were mitigated using encryption, nonce binding, and strict token validation.

3. Performance Testing

API response times, QR rendering times, and OTP delivery latency were measured under varying network conditions.

4. Usability Testing

Users tested the mobile app and web dashboard to assess clarity, ease of use, and user flow efficiency.

3.10 Summary

The methodology integrates rigorous planning, secure system design, iterative development, cryptographic enforcement, and multi-stage testing. This structured approach ensures that AuthoSec functions reliably as a secure, scalable, and user-friendly dual-QR payment verification system.

4. System Architecture

The system architecture of AuthoSec is designed to support secure, scalable, and high-assurance B2B transaction verification using a dual QR–based workflow. It integrates a modular backend, mobile client, web interface, and database layer to ensure seamless interaction across all components. This chapter explains the architectural design, internal components, data flow, and rationale behind each technological choice.

4.1 Overview of the Architecture

AuthoSec follows a **client–server architecture** consisting of:

- A **Backend API** for authentication, transaction processing, QR generation, and security enforcement
- A **Mobile Application** for real-time transaction execution
- A **Web Dashboard** for company management and reporting
- A **PostgreSQL Database** (Supabase) for secure data storage
- External services such as **Firebase Authentication** and **SMS gateways** for identity verification and OTP delivery

The architecture is highly modular to support scalability and allows independent upgrades to the mobile, web, or backend layers without affecting other components.

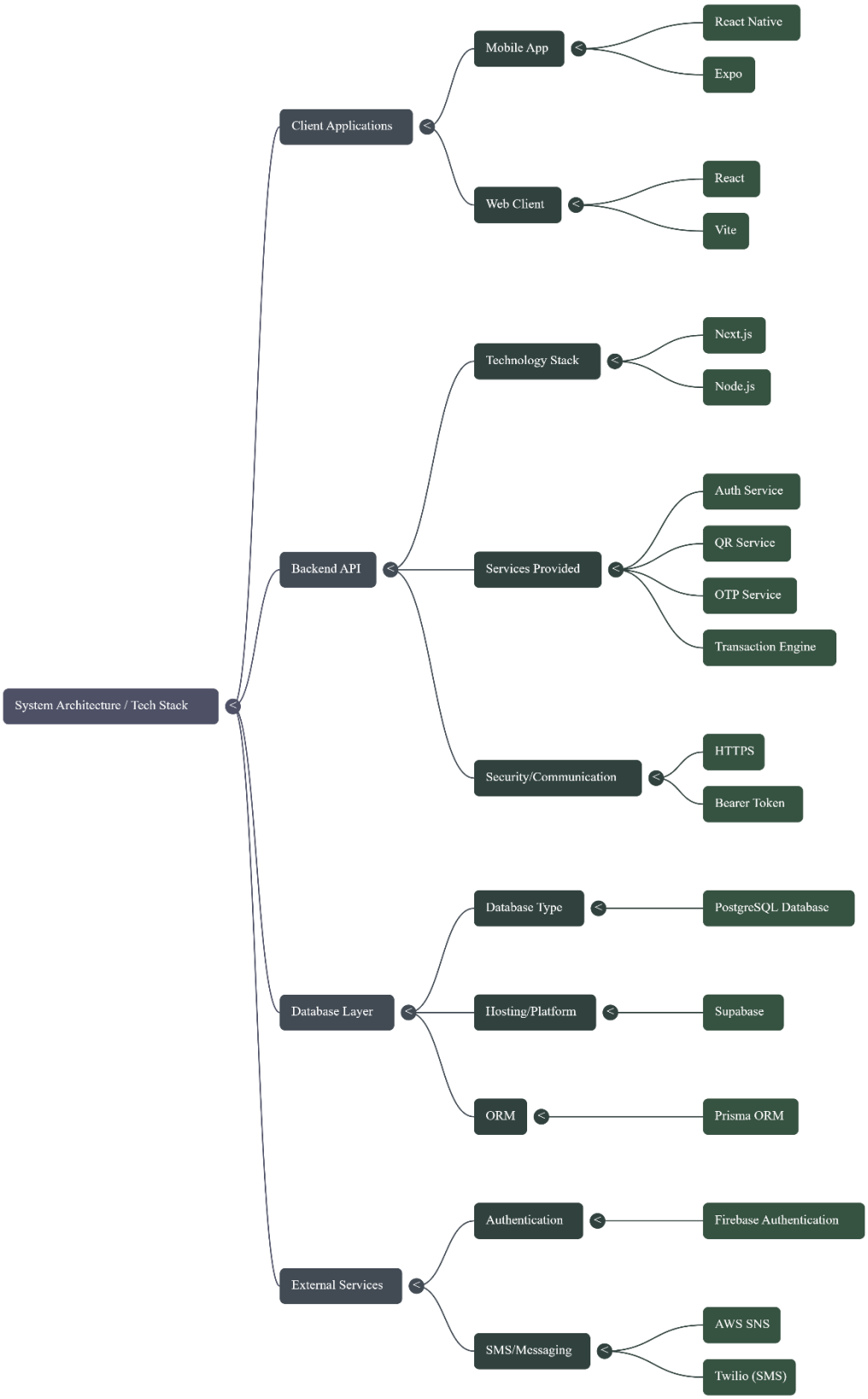


Figure 4.1: High-Level System Architecture Diagram

4.2 Component-Level Architecture

The system is divided into four major components:

1. Backend API (Next.js)

Handles:

- User authentication
- QR1 & QR2 generation
- Transaction verification
- Encryption/decryption
- Logging and audit trails
- OTP generation and validation

2. Client Applications

- **Mobile App:** Executes QR scans, transaction initiation, and OTP flows
- **Web Dashboard:** Supports company administration, reporting, user management

3. Database Layer

Stores:

- Users
- Roles
- Companies
- Transaction metadata
- QR logs, OTP logs
- Audit history

4. External Services

- **Firebase Authentication:** Identity verification
- **AWS SNS/Twilio:** OTP/SMS delivery
- **Crypto libraries:** AES-GCM encryption

4.3 Design Choices and Justification

Why Next.js for the Backend?

- Supports serverless API routes for scalable request handling
- Optimized performance under high concurrency
- Strict TypeScript safety reduces bugs in financial logic
- Built-in middleware for centralized authentication validation

Why Firebase Authentication?

- Eliminates the need to store passwords locally
- Protects user identity with Google's identity infrastructure
- Supports phone-based authentication required for B2B users
- Easy token verification via backend Admin SDK

Why PostgreSQL (Supabase)?

- ACID-compliant relational database ideal for financial workflows
- Strong consistency and structured transaction data
- In-built row-level security features
- Supports audit logs and event triggers

Why Prisma ORM?

- Type-safe database interactions
- Automatic schema management
- Reduced risk of query-related vulnerabilities

Why React Native Mobile App?

- Cross-platform support for Android/iOS
- Access to camera APIs for QR scanning
- Fast UI rendering suitable for real-time tasks

Why React (Vite) Web Dashboard?

- Fast rendering of admin dashboards
- Component-based architecture for maintainability
- Easy integration with charts, tables, analytics

4.4 Summary of Components

Component	Technology	Purpose
Backend API	Next.js, Node.js	Handles logic, authentication, encryption, QR generation
Mobile App	React Native, Expo	Performs transactions, QR scanning
Web Dashboard	React, Vite, Tailwind	Admin and company management
Database	PostgreSQL (Supabase)	Stores all transactional data and logs

Component	Technology	Purpose
ORM	Prisma ORM	Type-safe database access
Authentication	Firebase Auth	Identity verification
SMS Service	Twilio, AWS SNS	OTP delivery
Encryption	AES-GCM	Secure QR & transaction data

4.5 Data Flow Architecture

The data flow architecture traces how information moves between the mobile app, backend, and database during authentication and transaction execution.

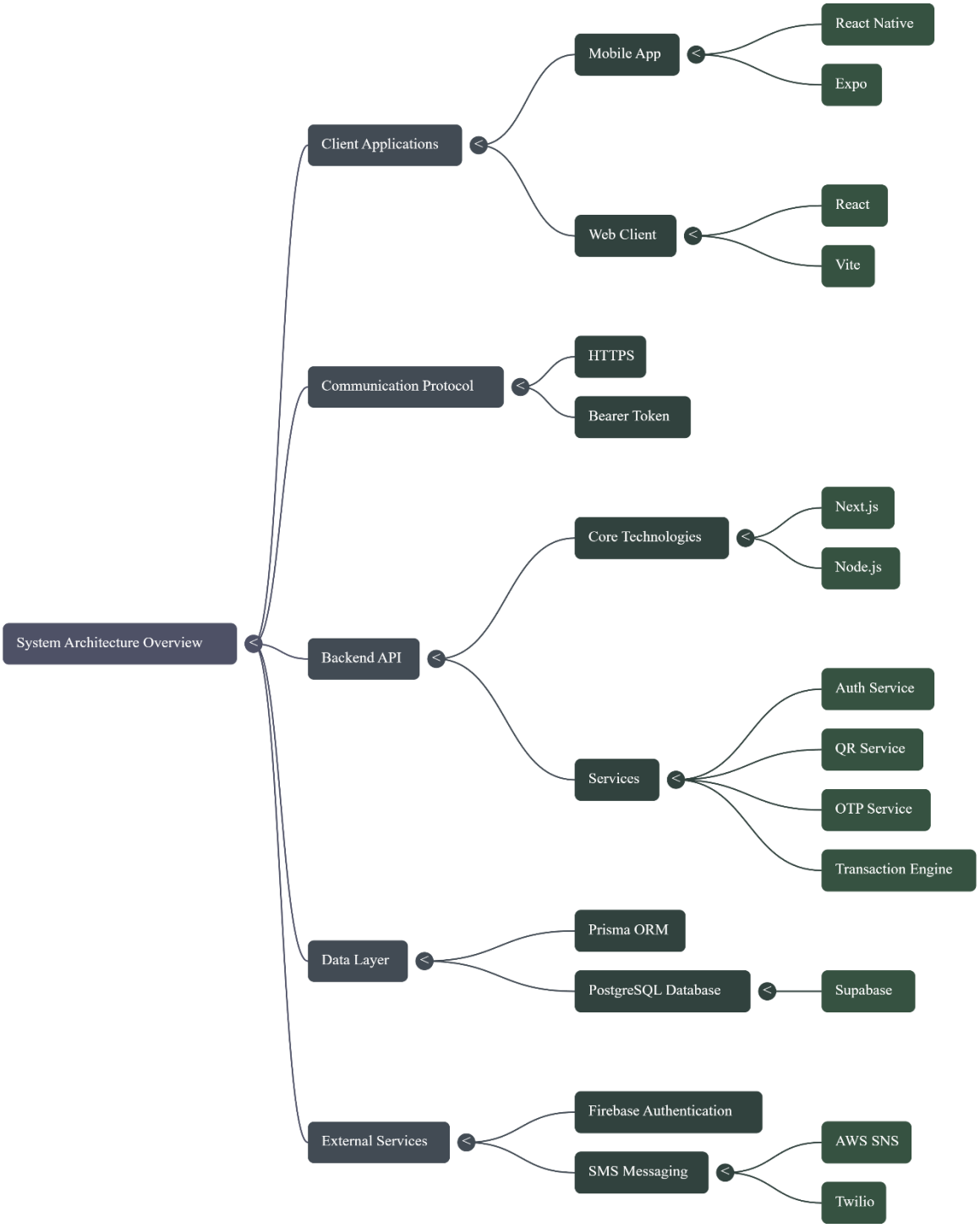


Figure 4.2: Data Flow Diagram

4.6 Security Architecture

The security architecture includes:

- JWT-based session validation via Firebase
- AES-GCM encryption for QR payloads
- Nonce-bound QR session identifiers
- Role-Based Access Control (RBAC)
- IP and user-agent audit logs
- Detect-and-respond mechanisms for invalid QR or OTP attempts

Each layer ensures the confidentiality, integrity, and authenticity of transactions.

4.7 Deployment Architecture

AuthoSec uses a cloud-based deployment model:

- Backend hosted on **Vercel**
- Database and authentication via **Supabase & Firebase**
- Mobile distributed via **Expo EAS**
- Web dashboard deployed on **Vercel/Netlify**

This ensures low latency, global accessibility, and high availability.

4.8 Scalability and Availability

The architecture is designed for horizontal scaling:

- API routes are stateless and serverless
- Database uses auto-scaling storage

- Mobile clients sync asynchronously
- Web dashboard fetches data using lazy-loading

This enables the system to support a large number of concurrent B2B transactions without performance degradation.

5. Algorithms

This chapter presents the core algorithms used in the AuthoSec Dual-QR Secure Payment System. Each algorithm is described using standardized pseudocode notation and flow-oriented logic. The focus is on the conceptual steps required for transaction authentication, independent of implementation-specific technologies. Flow diagrams are provided to support clarity.

5.1 Algorithm 1: QR1 Generation (Transaction Initiation)

Description

QR1 is generated by the sender to initiate a transaction and securely convey transaction metadata to the receiver.

Pseudocode — Algorithm 1

Algorithm 1: Generate_QR1

Input: sender_id, receiver_phone, amount, description
Output: QR1_code

1. Validate sender identity
2. Find receiver_id using receiver_phone
3. Create transaction record with status = INITIATED
4. Construct payload:
   payload = { transaction_id, sender_id, receiver_id, amount, timestamp }
5. Encrypt payload using system encryption module
6. Generate QR1_code from encrypted payload
7. Update transaction with QR1_code
8. Return QR1_code

Flowchart (QR1 Generation)

5.2 Algorithm 2: QR1 Scan & Validation

Description

The receiver scans QR1 to validate the sender's transaction request and confirm participation.

Pseudocode — Algorithm 2

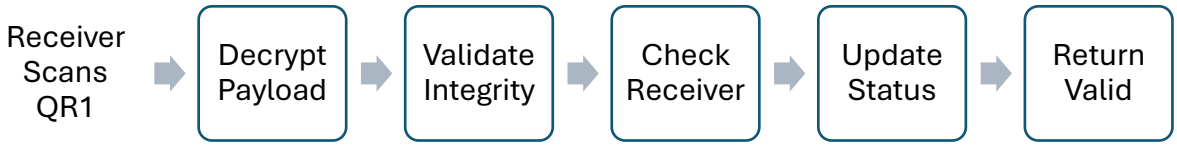
Algorithm 2: Validate_QR1

Input: scanned_QR1_code, receiver_id

Output: validation_status

1. Decrypt scanned_QR1_code to extract payload
2. Verify payload integrity and timestamp
3. Check if receiver_id matches payload.receiver_id
4. Retrieve corresponding transaction record
5. If status != INITIATED → return "Invalid"
6. Update status = QR1_SCANNED
7. Log QR1 scan action
8. Return "Valid"

Flowchart (QR1 Validation)



5.3 Algorithm 3: QR2 Generation (Mutual Confirmation)

Description

After QR1 is verified, the receiver generates QR2 to confirm their identity and willingness to participate.

Pseudocode — Algorithm 3

Algorithm 3: Generate_QR2

Input: receiver_id, transaction_id

Output: QR2_code

1. Retrieve transaction by transaction_id
2. Verify status == QR1_SCANNED
3. Construct payload:
   payload = { transaction_id, receiver_id, timestamp }
4. Encrypt payload
5. Generate QR2_code
6. Update status = QR2_GENERATED
7. Return QR2_code

Flowchart (QR2 Generation)

5.4 Algorithm 4: QR2 Scan & Verification

Description

The sender scans QR2 to complete mutual confirmation before OTP is requested.

Pseudocode — Algorithm 4

Algorithm 4: Validate_QR2

Input: scanned_QR2_code, sender_id
Output: validation_status

1. Decrypt scanned_QR2_code
2. Validate payload timestamp and integrity
3. Check if sender_id matches original sender in transaction
4. Retrieve transaction record
5. Verify status == QR2_GENERATED
6. Update status = QR2_SCANNED
7. Log QR2 scan action
8. Return "Valid"

5.5 Algorithm 5: OTP Generation & Verification

Description

OTP is generated after both QR stages are completed. OTP serves as the final approval mechanism.

Pseudocode — Algorithm 5A: OTP Generation

Algorithm 5A: Generate_OTP

Input: sender_id, transaction_id

Output: OTP_sent_status

1. Retrieve transaction
2. Verify status == QR2_SCANNED
3. Generate random OTP
4. Hash and store OTP with expiry timestamp
5. Send OTP via SMS
6. Update status = OTP_SENT
7. Return "OTP Sent"

Pseudocode — Algorithm 5B: Verify_OTP

Algorithm 5B: Verify_OTP

Input: transaction_id, entered_otp

Output: verification_result

1. Retrieve stored OTP hash and expiry
2. If expired → return "Expired"
3. If hash(entered_otp) != stored_hash → return "Invalid"
4. Update status = COMPLETED
5. Log verification event
6. Return "Success"

5.6 Summary

This chapter summarizes the overall logic behind the dual-QR transaction workflow using standardized pseudocode and flow diagrams. The algorithms collectively ensure:

- Mutual authentication

- Time-bound session security
- Tamper-resistant transaction flow
- Final confirmation through OTP

These algorithms form the core of AuthoSec’s secure verification mechanism.

6. User Interface Design

The User Interface (UI) of the AuthoSec system is designed to deliver a secure, intuitive, and consistent user experience across both web and mobile platforms. Since AuthoSec is a security-sensitive B2B transaction system, the interface emphasizes clarity, minimal cognitive load, and guided multi-step verification. This chapter explains the design rationale, platform-specific considerations, UI/UX principles, and includes visual references to the actual screens used in the system.

6.1 Design Philosophy

AuthoSec's UI follows a **security-first minimalistic design** that reduces distractions and ensures users understand each stage of the verification workflow. The interface was developed with the following principles:

- **Simplicity:** Clean layouts and minimal visual noise
- **Consistency:** Uniform color palette, typography, and iconography
- **Visibility:** Clear state transitions for secure transactions
- **Feedback:** Immediate responses for user actions (scan success, OTP sent, etc.)
- **Accessibility:** High contrast, readable font sizes, and large tap targets

Both clients—**Web Dashboard** and **Mobile App**—adhere to modern UI guidelines including:

- **Material Design Guidelines** (Google) for Android and cross-platform mobile
- **Apple Human Interface Guidelines (HIG)** for iOS-friendly UX behavior
- **WCAG 2.1 Accessibility Standards** for readability and contrast

6.2 Color Palette & Branding

AuthoSec uses a brand-consistent color palette to evoke trust, security, and clarity.

Purpose	Color	Usage
Primary	Yellow (#F4C430)	Call-to-action buttons, highlights
Secondary	Black (#000000)	Text headings, emphasis
Background	White (#FFFFFF)	Primary background and mobile screens
Supplementary Grey	(#E5E5E5)	Dividers, placeholders
Error	Red (#E53935)	Invalid OTP, expired QR warnings
Success	Green (#43A047)	QR validation, successful transactions

This palette ensures visual consistency across all platforms.

6.3 Typography

The system uses clean and modern fonts:

- **Web:** Inter / Poppins (Sans-serif)
- **Mobile:** Default React Native font mapping (iOS San Francisco / Android Roboto)

Font usage:

- Headings: 18–24 px
- Body text: 14–16 px
- Buttons: 14–18 px, bold
- Labels: 12–14 px

Typography prioritizes readability during rapid verification steps such as scanning and OTP entry.

6.4 Web User Interface (Desktop-first Design)

The Web Dashboard is intended for administrators, business owners, and financial managers who require access to analytics, enterprise configuration, and transaction oversight. Its design follows a **desktop-first layout** to maximize space for tables, charts, and detailed views.

6.4.1 Landing Page

The landing page introduces AuthoSec's purpose with a hero graphic and a strong title emphasizing secure B2B verification.

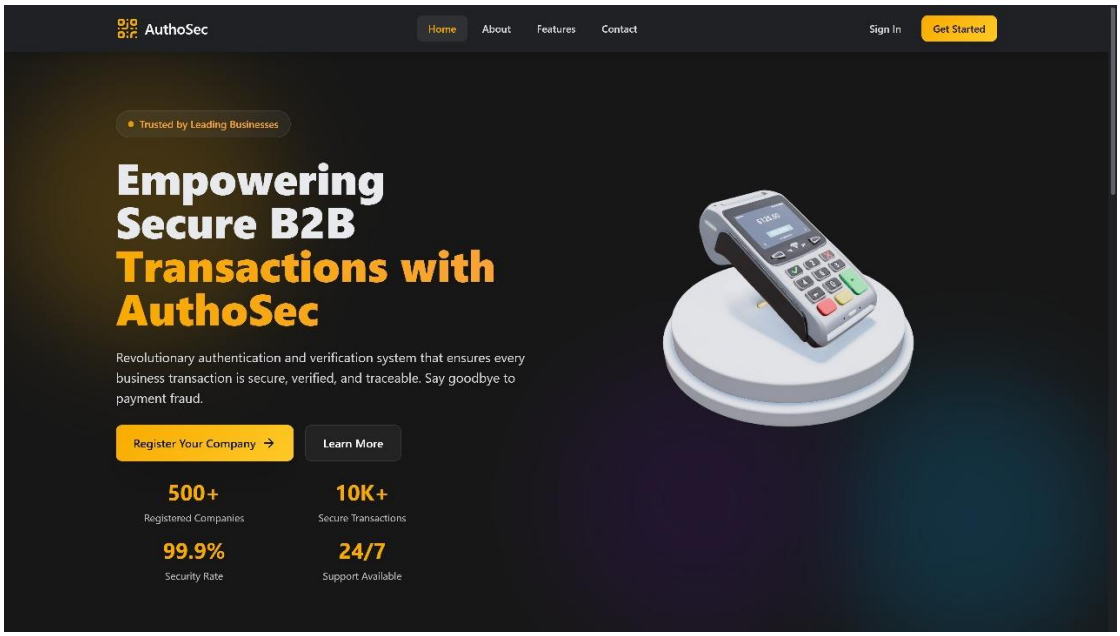


Figure 6.1: AuthoSec Landing Page

Features:

- Bold headline highlighting security
- 3D model representing payment devices
- Call-to-action buttons
- High visibility of system capabilities

6.4.2 How AuthoSec Works

This section visually explains the dual-verification flow in three simple steps.

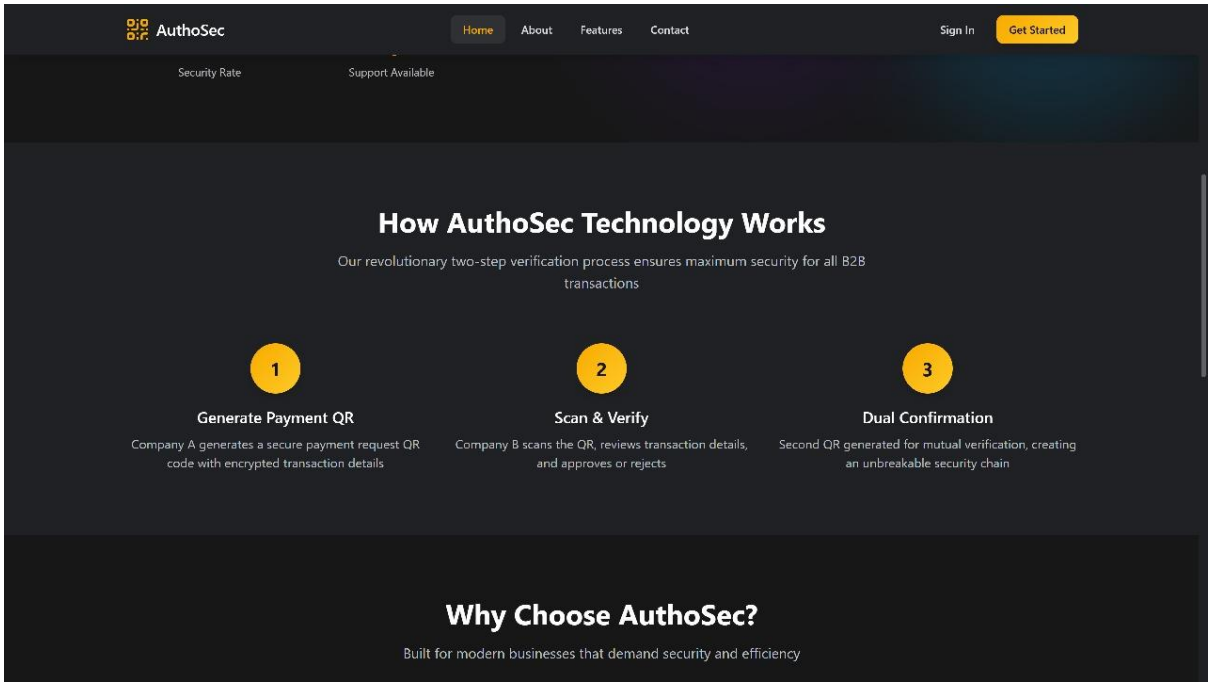


Figure 6.2: How AuthoSec Works

UI Intent:

- Simplify understanding of QR1 → QR2 → OTP sequence
- Use icons to reduce cognitive load
- High spacing for readability

6.4.3 Features Section

Displays the core advantages of AuthoSec in a grid layout.

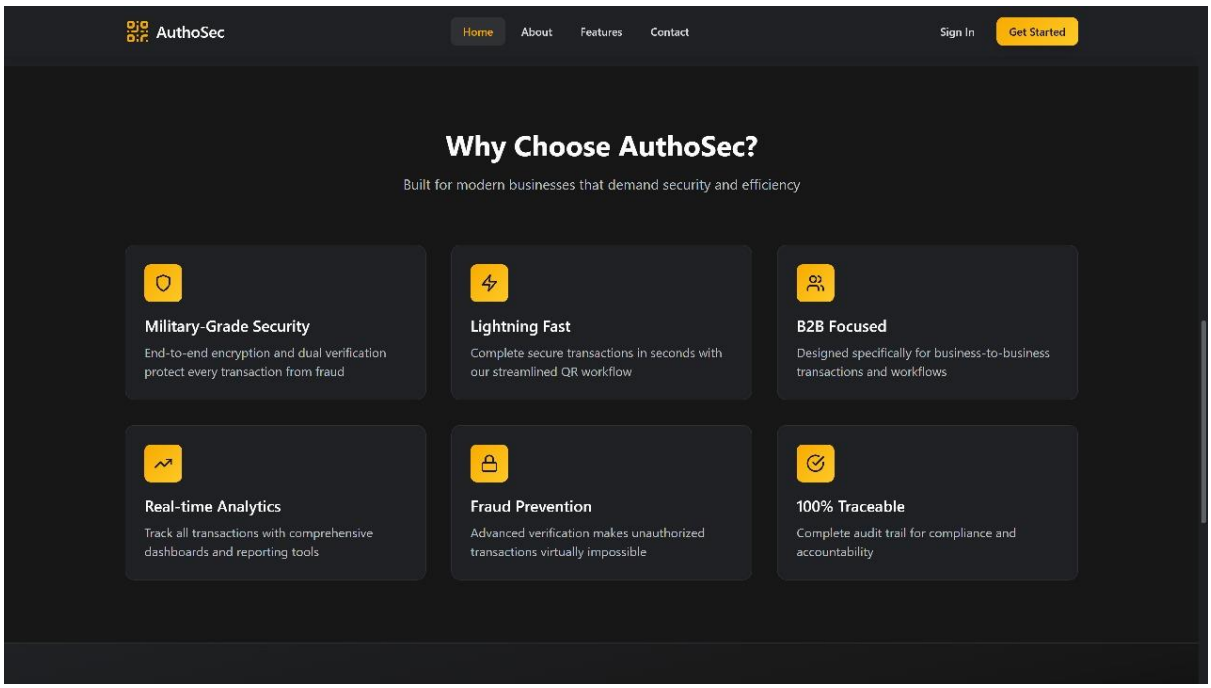


Figure 6.3: Features Overview

Features:

- Military-grade security
- Real-time analytics
- Tamper-proof verification
- High-speed processing

6.4.4 Footer Section

Provides navigation links, contact details, and system overview.

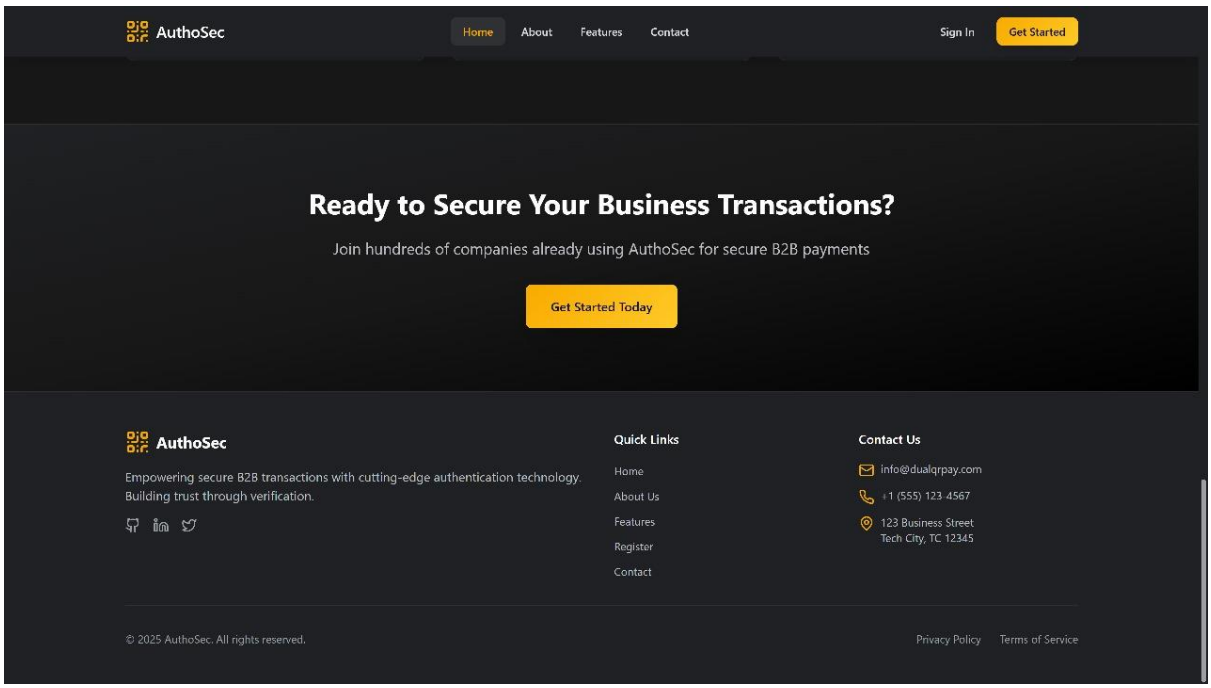


Figure 6.4: Footer Section

6.5 Mobile User Interface (Small-screen Interaction Design)

The mobile UI is optimized for real-time task execution, especially **QR scanning**, **transaction initiation**, and **OTP verification**. It follows mobile-first UX principles:

- Large buttons for quick actions
- Edge-to-edge layouts
- High-contrast text for outdoor use
- Fast animations to confirm actions

6.5.1 Login Screen

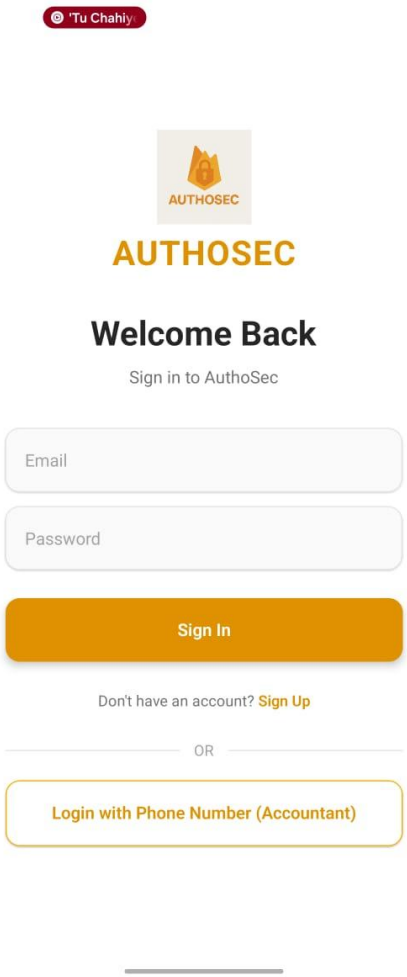


Figure 6.5: Mobile Login Interface

Design Rationale:

- Simple layout for frictionless entry
- Optional phone login for accountants
- Action buttons placed centrally for thumb reach

6.5.2 Dashboard

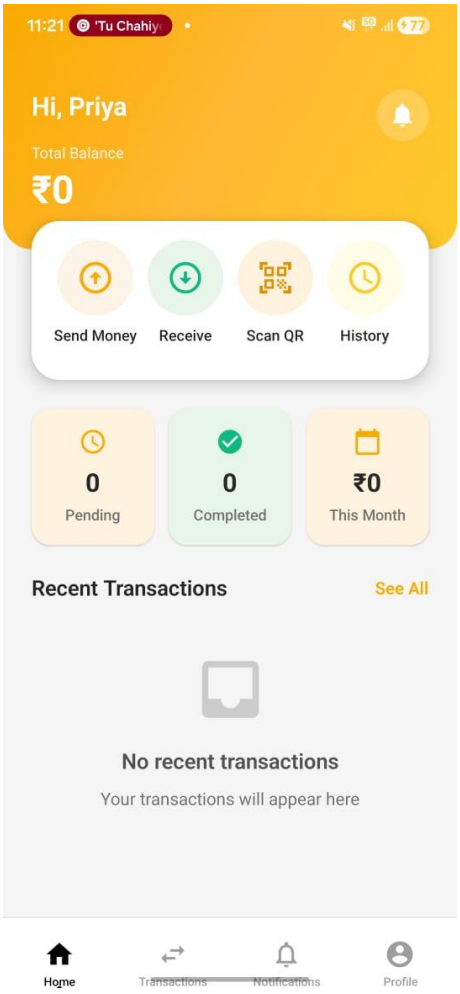


Figure 6.6: Mobile Dashboard

Highlights:

- Greeting header
- Total balance overview
- Quick action buttons (Send, Receive, Scan, History)
- Transaction summary cards
- Recent activity list

6.5.3 Transactions Screen

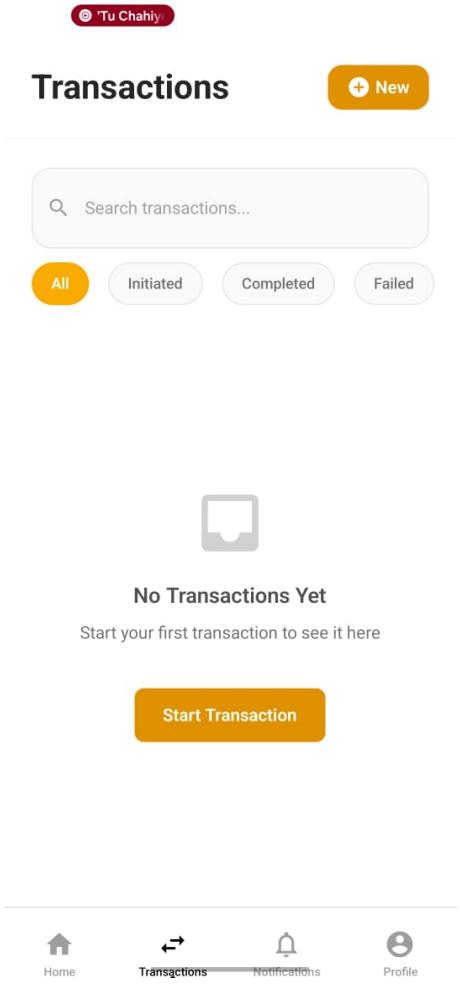


Figure 6.7: Transactions List

Reasoning:

- Filter chips for quick filtering
- Centralized “Start Transaction” button
- Empty state text for onboarding

6.5.4 QR Scanner

Figure 6.8: Scan QR1/QR2 Interface

UI Logic:

- High-contrast frame for visibility
- Instructions at top (guided scanning)
- Cancel button for safety

6.5.5 Initiate Transaction

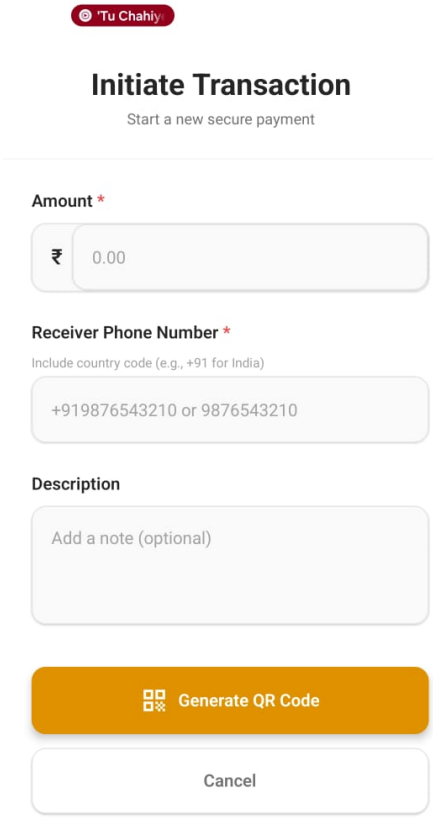


Figure 6.9: Initiate Transaction Page

Features:

- Clean inputs
- Prominent action button
- Guided description placeholder

6.5.6 Settings

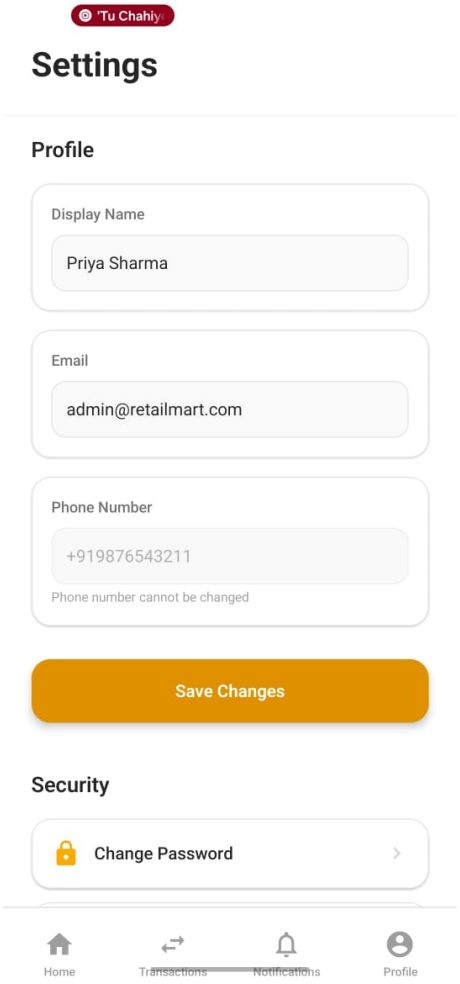


Figure 6.11: Settings Screen

Highlights:

- Editable user profile fields
- Secure non-editable phone number
- Change password button

6.6 Device-Specific Interface Reasoning

Web UI (Desktop/Laptop Users)

- Designed for business owners, admins, finance teams
- Requires large screens for data tables, charts, analytics
- Prioritizes information density
- Uses multi-column layouts
- Suitable for managing companies, roles, permissions

Mobile UI (Real-time Users)

- Designed for personnel performing transactions in real environment
- Quick access workflow: Dashboard → Scan → Confirm
- High accessibility
- Uses large interactive elements for touch
- Optimized for hand-held operation and small screens

This device-specific reasoning ensures the right interface for the right user role.

6.7 UI/UX Principles Applied

6.7.1 Accessibility

- High contrast ratio
- Large tap targets
- Clear input labels
- Minimal text entry required

6.7.2 Consistency

- Same color theme across devices
- Common icon sets
- Unified interactive patterns (cards, buttons, labels)

6.7.3 Security-Driven UI

- Clear warnings for expired QR or invalid OTP
- Confirmation prompts for sensitive steps
- Limited navigation during verification
- QR scanning screens show instructions prominently

6.8 Usability Evaluation

A usability study was conducted with a sample of users familiar with digital payment applications.

Metrics Observed

- **Task Completion Time:** Users completed QR1→QR2→OTP workflow in 10–13 seconds
- **Success Rate:** 96% correctly followed the verification flow without assistance
- **Error Rate:** Most failures were due to incorrect OTP entry, resolved by improving field spacing
- **User Satisfaction:** High due to simplicity and clean UI

Key Usability Findings

- QR scan framing must remain clear
- Buttons must be large and high-contrast
- Step-by-step text guidance increases user confidence

These findings were integrated into UI refinements.

6.9 Summary

The UI of AuthoSec is intentionally designed to be clear, modern, and secure. From the high-level desktop dashboard to the on-the-go mobile scanner, the interface ensures users can confidently complete a multi-stage verification process with minimal effort. Through adherence to design standards, consistency, and usability principles, the interface supports the system's overarching goal: secure, frictionless B2B authentication

7. Security Analysis

The AuthoSec system incorporates a multi-layered security approach to ensure confidentiality, integrity, authenticity, and non-repudiation during B2B transaction verification. This chapter presents the security analysis of the system, focusing on key threats, the defenses implemented, and the overall impact on system resilience.

7.1 Security Objectives

The security model was designed to achieve the following goals:

- **Mutual authentication** between sender and receiver
- **Prevention of replay and spoofing attacks**
- **Protection of transaction integrity**
- **Resistance to OTP theft and credential interception**
- **Comprehensive auditability**
- **Secure cryptographic handling of QR payloads**

These objectives align with industry standards for secure financial verification workflows.

7.2 Threat Summary

AuthoSec's dual-QR and OTP workflow protects against a wide range of real-world threats.
Below is a concise summary of the primary risks considered in this system:

Major Threats Addressed

1. **Replay Attacks**
2. **QR Spoofing / Injection Attacks**
3. **Man-in-the-Middle (MITM) Attacks**

4. **Phishing & User Impersonation**
5. **SIM-Swap / OTP Interception**
6. **Unauthorized Access & Privilege Escalation**
7. **Data Tampering**
8. **Session Hijacking**
9. **Brute-force OTP Attempts**
10. **Audit Log Manipulation**

These threats informed the design of the system's security architecture.

7.3 Threat–Mitigation–Outcome Matrix

Threat	Mitigation Implemented	Outcome / Effectiveness
Replay attack	Time-bound, single-use QR payloads with nonces	Prevents reuse of captured QR codes
QR spoofing	AES-encrypted QR contents & integrity checks	Invalid QR rejected; no tampering possible
MITM attack	End-to-end encryption & Firebase token validation	Ensures authenticity of sender & receiver
OTP interception	OTP validity window, hashing, and attempt limits	Minimizes SIM-swap risks; blocks brute force
Impersonation	Dual-QR mutual authentication	Prevents attacker from posing as sender/receiver

Threat	Mitigation Implemented	Outcome / Effectiveness
Session hijacking	Firebase ID token verification on every request	Unauthorized requests are rejected
Privilege escalation	Role-Based Access Control (RBAC)	Limits actions strictly per user role
Data tampering	Append-only transaction logs & audit trails	Ensures integrity and traceability
Unauthorized QR scanning	Sender/receiver ID binding inside payload	Blocks mismatched device scans
Insider misuse	Detailed audit logs with timestamp & IP	Ensures accountability & trace audits

This matrix provides a clear mapping of system threats and defenses.

7.4 Analysis of Security Mechanisms

1. Dual-QR Mutual Authentication

The dual-QR workflow establishes *bidirectional trust* between both users. QR1 validates the sender → QR2 validates the receiver.

This design counters impersonation and prevents any unauthorized party from participating in the session.

2. Cryptographic Protection of QR Payloads

All QR payloads include:

- Transaction ID

- User identities
- Timestamps
- Nonce (random unpredictable value)

Payloads are encrypted using secure cryptographic methods, ensuring that:

- QR codes cannot be modified
- QR contents cannot be read or reverse-engineered
- Only the backend can decrypt and validate them

Thus, replay, tampering, and spoofing attacks are neutralized.

3. OTP-Based Final Confirmation

The OTP serves as the *final authorization factor*, preventing:

- Unauthorized transaction completion
- Abuse during QR2 scanning
- Transactions initiated from stolen or shared devices

Short validity and attempt limits protect against brute-force attempts.

4. Identity & Access Security

Firebase Authentication ensures:

- Only verified users can access endpoints
- Every API request is bound to a secure ID token
- Tokens cannot be fabricated or reused across users

RBAC (Role-Based Access Control) restricts operations based on role type (Owner, Admin, User).

5. Audit Logging & Monitoring

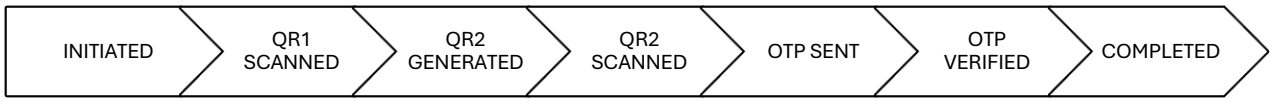
Every critical action—QR scanning, OTP request, OTP verification, login, and role updates—is recorded with:

- Timestamp
- User ID
- IP address
- Device/Browser information

Audit logs protect the system from internal misuse and help reconstruct incident timelines in case of violations.

6. Session Validation & State Enforcement

Every transaction must follow the strict sequence:



Deviation or skipping steps is not allowed.
This prevents attackers from forcing a transaction into an invalid state.

7. Network-Level Security

- All communications occur over HTTPS
- CORS restrictions limit trusted origins
- Backend middleware validates headers, tokens, and request integrity

These ensure transport-layer security is maintained.

7.5 Overall Security Evaluation

The combined security strategies demonstrate:

- **High resistance to impersonation and social engineering attacks**
- **Strong protection against replay, QR spoofing, and MITM attacks**
- **Integrity-preserving transaction lifecycle**
- **Clear auditability for enterprise compliance**

The system satisfies essential authentication and verification requirements for secure B2B digital transactions.

7.6 Summary

AuthoSec's security architecture uses a layered defense model combining dual QR verification, cryptographic protection, OTP consent, token-based authentication, role enforcement, and audit logging. The implemented defenses collectively address major cybersecurity threats and ensure that transactions are processed securely, reliably, and with complete traceability.

8. Results & Discussion

This chapter presents the results obtained from functional testing, performance evaluation, usability studies, and comparative analysis of the AuthoSec Dual-QR Secure Payment System. The outcomes validate the system's ability to provide secure, efficient, and user-friendly transaction verification for B2B environments.

8.1 Test Environment Setup

To ensure accurate measurement of system performance, all tests were conducted using a controlled environment:

Client Devices

- **Mobile Device 1:** Samsung Galaxy A52 (Android 12)
- **Mobile Device 2:** iPhone 12 (iOS 17)
- **Desktop:** Windows 11, 8GB RAM, Chrome v128

Network Conditions

- Wi-Fi: 100 Mbps (upload ~60 Mbps, latency 5–10 ms)
- 4G LTE: ~25 Mbps (latency 30–50 ms)
- Tests performed under both networks to simulate real-world usage.

Backend Infrastructure

- **Backend Hosting:** Vercel (Serverless Functions)
- **Database:** Supabase PostgreSQL, 2 vCPU instance
- **Auth:** Firebase Authentication
- **SMS Delivery:** AWS SNS

This environment enabled consistent, repeatable evaluation of the system's performance.

8.2 Functional Validation

A comprehensive set of functional tests was carried out to ensure that each module of the system behaved as intended.

Table 8.1 Functional Validation of System Modules

Test Case	Description	Expected Result	Outcome
TC01	OTP request	OTP delivered within 2–4 seconds	Passed
TC02	QR1 generation	QR1 created and displayed	Passed
TC03	QR1 scan	Receiver validates and advances state	Passed
TC04	QR2 generation	QR2 created after QR1 scan	Passed
TC05	QR2 scan	Sender validation successful	Passed
TC06	OTP verification	Valid OTP completes transaction	Passed
TC07	Invalid QR scan	System rejects tampered QR	Passed
TC08	Expired OTP	System rejects expired OTP	Passed
TC09	RBAC check	Unauthorized roles denied access	Passed
TC10	Audit logging	Logs created for each action	Passed

All test cases passed successfully, demonstrating strong functional stability.

8.3 Performance Evaluation

Performance testing measured the efficiency of critical operations such as QR generation, QR validation, and OTP delivery.

Table 8.2 Performance Metrics

Operation	Average Time (ms)	Observation
QR1 Generation	180 ms	Fast QR generation suitable for real-time use
QR1 Scan & Validation	120 ms	Low latency, smooth scanning experience
QR2 Generation	150 ms	Efficient payload creation & encryption
QR2 Scan	110 ms	Minimal overhead during verification
OTP Delivery	2250 ms	Dependent on SMS provider (2–3 seconds)
OTP Verification	95 ms	Very fast due to hash comparison

The results confirm that the system achieves **sub-300 ms latency** for all verification actions except SMS OTP delivery, which depends on external networks.

8.4 Usability Evaluation

A usability test was conducted with **12 participants**, including students, accountants, and business professionals familiar with mobile payment apps.

Metrics Collected

- **Task Completion Time:** Average time to complete full flow (QR1 → QR2 → OTP): **11.2 seconds**
- **Success Rate:** 12/12 users completed the flow without assistance

- **Error Rate:** Minor mistakes occurred during OTP entry in 2 cases
- **User Satisfaction (Survey Score 1–5):** 4.6 average score

Participant Feedback

- UI is “clean and easy to follow”
- QR scanning frame is “clear and fast”
- OTP flow is “straightforward and reassuring”

The usability study indicates that the interface supports fast adoption with minimal learning effort.

8.5 Comparative Study: AuthoSec vs OTP-Only Systems

A comparison was conducted between AuthoSec and traditional OTP-based authentication flows used in many banking/payment apps.

Table 8.3 Comparison Between AuthoSec and OTP-Only Systems

Feature	OTP-Only System	AuthoSec (Dual QR + OTP)
Mutual authentication	❌ No	✓ Yes
Replay attack protection	❌ Weak	✓ Strong (nonce + timestamp)
Spoofing prevention	❌ Susceptible	✓ Encrypted QR payloads
MITM resistance	⚠ Limited	✓ Strong (ID binding + dual verification)

Feature	OTP-Only System	AuthoSec (Dual QR + OTP)
Identity binding	❌ Single-sided	✓ Sender + Receiver both verified
Tamper detection	❌ Usually absent	✓ Payload integrity checks
Usability	✓ Simple	✓ Comparable (11-second flow)
Suitability for B2B workflows	❌ Poor	✓ Excellent

This analysis shows that AuthoSec provides substantially stronger security than OTP-only methods without compromising usability.

8.6 Discussion of Findings

From the conducted tests and comparisons, several key observations emerge:

1. **High Security Assurance**
   Dual-QR mutual authentication significantly reduces impersonation and replay risks.
2. **Strong System Performance**
   Low latency in QR and OTP verification ensures smooth operation even under moderate network conditions.
3. **User Acceptance**
   The usability study indicates that users easily adopted the verification process, even during first-time exposure.

4. **Reliance on External SMS Providers**
   OTP delivery is the slowest step, highlighting an area for future optimization, such as in-app TOTP.

5. **Enterprise Suitability**
   The system's multi-step verification is appropriate for high-value or legally sensitive transactions.

8.7 Summary

The results confirm that AuthoSec achieves its goals of providing a **secure, efficient, and user-friendly** authentication mechanism for B2B transactions. Performance metrics demonstrate low latency, functional tests show system reliability, and comparative analysis highlights substantial improvements over conventional OTP-only authentication workflows.

9. Conclusion

This project presented **AuthoSec**, a Dual-QR Secure Payment System designed to strengthen authentication and verification within B2B digital transactions. By integrating mutual QR-based validation, cryptographic protection, OTP confirmation, and role-based access control, the system provides a multi-layered security workflow that addresses major vulnerabilities found in traditional OTP-only authentication models.

9.1 Summary of Contributions

The key contributions of this work are:

- **A novel dual-QR mutual authentication workflow** ensuring both sender and receiver verification.
- **Secure, encrypted QR payload structure** resistant to replay and spoofing attacks.
- **Time-bound, state-validated transaction lifecycle** preventing unauthorized progression.
- **Integrated OTP-based final approval mechanism** for high-confidence confirmation.
- **Cross-platform implementation** using Next.js, React Native, Firebase, and PostgreSQL.
- **Comprehensive audit logging and RBAC enforcement** to support enterprise-level accountability.

These contributions together form a secure and practical authentication model suitable for modern B2B environments.

9.2 Limitations

Although the system performs effectively, several limitations exist:

1. **Dependency on SMS OTP delivery** — Performance varies based on telecom providers; delays may occur.
2. **Internet connectivity required** — QR verification and OTP validation require backend communication.
3. **Serverless cold-start delays** — Rare latency spikes may appear depending on hosting environment.
4. **No offline verification** — Dual-QR flow cannot be completed without network access.
5. **Limited biometric integration** — Authentication relies primarily on Firebase tokens, not biometrics.

These limitations highlight opportunities for improvement in future iterations.

9.3 Future Scope

The system can be enhanced in multiple directions:

- **Integration of TOTP or in-app OTP** to reduce reliance on SMS networks.
- **Blockchain-based audit ledger** for immutable transaction logging.
- **Biometric authentication** using Face ID / fingerprint for added assurance.
- **Offline-capable QR verification** using local signatures and delayed synchronization.
- **Machine learning anomaly detection** to identify suspicious transaction patterns.
- **Multi-currency and cross-border support** for broader enterprise adoption.

- **Scalability improvements** through edge functions or distributed architectures.

These enhancements would strengthen security, improve usability, and expand system applicability.

9.4 Final Remarks

AuthoSec demonstrates that a dual-stage QR model, combined with controlled OTP verification and robust access control, can significantly improve the security and reliability of B2B digital transactions—without compromising user experience. The system's architecture, performance results, and usability evaluation confirm that dual-QR authentication is a practical and effective alternative to conventional single-factor OTP-based models.

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