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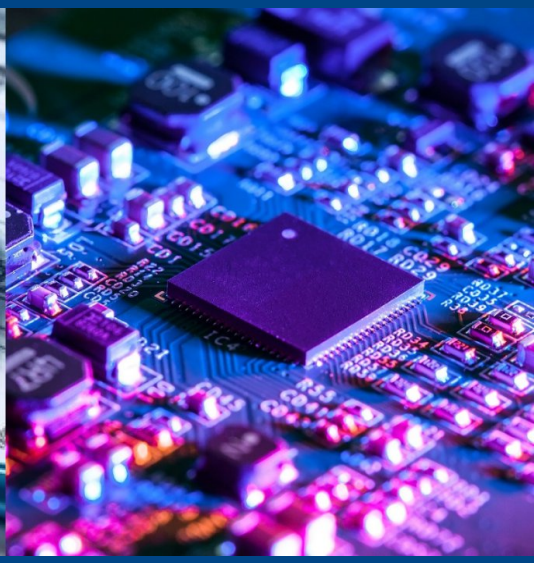

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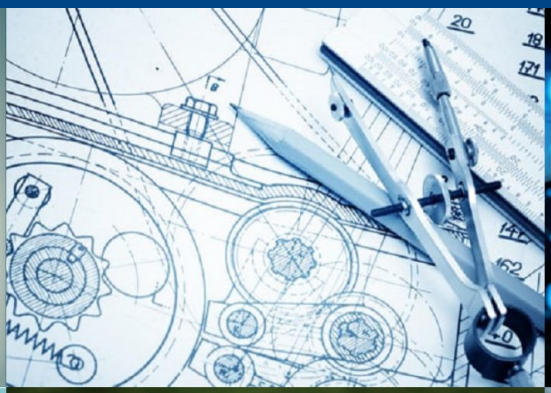

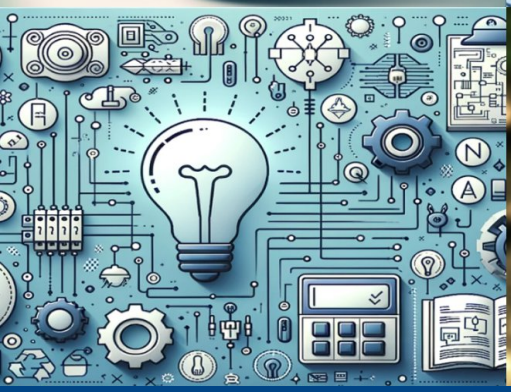

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Alcohol Limitation and Tracking System Using RFID

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ABSTRACT: Alcohol consumption has become a major public concern due to its profound impact on individual health, road safety, and social stability. Traditional monitoring approaches are largely manual, inconsistent, and fail to provide real-time enforcement or historical analytics. This paper proposes the Alcohol Limitation and Tracking System (ALTS), an RFID-integrated, full-stack web platform designed to automate and enforce alcohol purchase control in regulated environments. The system leverages RFID cards to uniquely identify users at point-of-sale, queries a centralized MongoDB database to evaluate consumption history against predefined daily and weekly limits, and delivers instant allow/deny decisions via a Node.js and Express.js backend. A responsive, role-based web frontend serves three distinct user roles — Administrator, Shop Operator, and End User — each with dedicated dashboards and analytical views powered by Chart.js. Real-time communication between the RFID scanner and the backend is facilitated by WebSockets, ensuring zero-polling overhead. The system maintains tamper-evident, timestamped transaction logs and supports configurable thresholds at both individual and category levels. Experimental results demonstrate accurate limit enforcement, seamless RFID integration, and scalable performance under concurrent usage. ALTS represents a practical, cost-effective, and ethically grounded approach to responsible alcohol distribution management.

KEYWORDS: RFID, Alcohol Monitoring, Access Control, Web Application, Node.js, MongoDB, Real-Time Tracking, JWT Authentication, WebSockets, Role-Based Dashboard

I. INTRODUCTION

Alcohol misuse is a pervasive global issue that contributes to millions of deaths annually, strains healthcare infrastructure, and precipitates traffic accidents, domestic violence, and reduced workplace productivity. According to the World Health Organization (WHO), alcohol is a causal factor in over 200 distinct disease and injury conditions. In regulated retail environments such as government liquor outlets, bars, and institutional canteens, there exists a critical need for a technology-driven mechanism that can unobtrusively yet effectively monitor and limit individual alcohol purchases.

Existing control mechanisms are largely dependent on human supervisors, manual record-keeping, or static identity checks — all of which are inherently prone to circumvention, fatigue- related errors, and operational inconsistency. Furthermore, these approaches generate little usable data for longitudinal consumption analysis or policy enforcement.

This paper presents ALTS — the Alcohol Limitation and Tracking System — a comprehensive software and hardware solution that integrates RFID-based identity verification with a cloud-ready web application backend. The system is designed to issue real-time purchase decisions, maintain detailed consumption histories, and provide actionable analytics to administrators and shop operators. The architecture is built upon Node.js, Express.js, MongoDB, and vanilla JavaScript, making it lightweight, easy to deploy, and cost-effective for institutions of varying scale.

PROBLEM STATEMENT

Current alcohol purchase and monitoring systems exhibit several critical deficiencies that undermine effective consumption control:

- Absence of automated real-time enforcement: Manual checks at the point of sale are easily bypassed and do not scale to high-footfall environments.
- Lack of individual consumption tracking: Existing systems do not maintain per-user records across sessions, making

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enforcement of daily or weekly limits impossible.

- No centralized audit trail: Without an immutable transaction log, accountability and regulatory compliance are difficult to demonstrate.
- Reactive rather than preventive design: Human-supervised systems respond only after excessive consumption has already occurred.
- Data silos and limited analytics: Fragmented or paper- based records prevent data-driven insights into consumption patterns and policy effectiveness.

II. OBJECTIVES

The design and development of ALTS is guided by the following specific objectives:

1. To design a reliable RFID-based user identification mechanism operable at standard retail point-of-sale speeds.
2. To develop a secure, full-stack web platform implementing role-based access control for Administrators, Shop Operators, and End Users.
3. To enforce configurable per-user daily and weekly alcohol consumption limits through automated backend decision logic.
4. To implement a real-time WebSocket communication channel between RFID scanning hardware and the application server to minimize latency.
5. To persist comprehensive, timestamped purchase transaction records in MongoDB for audit and analytics purposes.
6. To provide data visualization dashboards with Chart.js for consumption trend analysis across all three user roles.
7. To validate system performance through integration testing under realistic concurrent-user scenarios.

III. LITERATURE REVIEW

RFID technology has been extensively adopted in access control, inventory management, supply chain logistics, and healthcare asset tracking due to its contactless, high-speed identification capabilities [1]. In the domain of behavioral monitoring, prior work has explored biometric and card-based systems for restricting access to controlled substances. Jayasree et al. [2] proposed a smart liquor shop management system employing RFID and a GSM-based notification module; however, their system lacked a web-based management interface and real-time consumption enforcement logic. Rajesh Kumar et al. [3] demonstrated RFID integrated with cloud databases for point-of-sale applications but did not address multi-role dashboards or limit policy management.

In the domain of web-based health monitoring, several studies have utilized Node.js and MongoDB for IoT-driven data aggregation due to their non-blocking I/O model and document- oriented storage flexibility [4]. WebSocket-based real-time communication has been widely validated as a superior alternative to polling for event-driven IoT applications [5].

Role-based access control (RBAC) models have been extensively studied in enterprise systems, with JSON Web Tokens (JWT) emerging as the de facto standard for stateless, scalable authentication in RESTful APIs [6]. Chart.js has been demonstrated as a lightweight, browser-native library well- suited for consumption analytics dashboards [7].

A key gap in the existing literature is the absence of a unified, fully-integrated system that combines RFID hardware interfacing, real-time WebSocket communication, multi-role web dashboards, policy-driven consumption enforcement, and longitudinal analytics within a single deployable platform. ALTS addresses this gap comprehensively.

IV. PROPOSED SYSTEM

ALTS is proposed as a unified hardware-software platform for regulated alcohol purchase environments. The core proposition is that every purchase transaction must be mediated by the system: a user presents an RFID card, the system evaluates current consumption against configured limits, and an immediate allow or deny decision is communicated to the shop operator within sub-second latency.

The system workflow is as follows:

8. The user presents their RFID card to the reader at the point of sale.
9. The RFID reader captures the card's unique UID and transmits it to the Node.js backend via a WebSocket connection.

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10. The backend queries MongoDB to retrieve the user's profile, consumption history, and applicable limit thresholds.
11. The enforcement engine evaluates whether the purchase would violate daily or weekly limits.
12. A real-time decision (ALLOW or DENY) is emitted back via WebSocket to the shop operator's dashboard.
13. If allowed, the transaction is recorded to MongoDB with a precise UTC timestamp, product category, and quantity.
14. All role-based dashboards update asynchronously to reflect the new transaction state.

V. SYSTEM ARCHITECTURE

The ALTS architecture follows a three-tier model: presentation layer, application logic layer, and data persistence layer.

A. Presentation Layer

The frontend is implemented in vanilla JavaScript with modular HTML5 and CSS3, deliberately avoiding heavyweight frameworks to maintain fast load times. Three distinct role- based dashboards are served: Admin Dashboard (system-wide analytics, user management, limit configuration, transaction logs), Shop Dashboard (live RFID scan result, queue management, daily summary), and User Dashboard (personal consumption history, remaining allowance, weekly trend charts).

B. Application Logic Layer

The backend is built on Node.js with Express.js, organized into RESTful API routes authenticated via JWT middleware. Key modules include: Authentication Module (JWT issuance and validation with role claims), RFID WebSocket Handler (persistent connections with scanning hardware), Enforcement Engine (rule evaluation against rolling time-window aggregations), Transaction Logger (atomic writes with full metadata), and Analytics API (aggregated data for Chart.js dashboards).

C. Data Persistence Layer

MongoDB serves as the primary database with Mongoose ODM for schema validation and query abstraction. The data flow is: RFID Reader → WebSocket → Node.js/Express Backend → MongoDB → Decision → REST API → JavaScript Dashboards.

VI. DATASET DESCRIPTION

ALTS operates on dynamically generated operational data. The primary data collections are described in Table I.

Collection	Key Fields	Description
User	UID, Name, Role, Limit	RFID card holder with limit policy
Transaction	UserID, Qty, Decision, Timestamp	Immutable scan event record
Shop	ShopID, Name, OperatorID	Registered point-of-sale outlet
Limit Policy	Daily, Weekly, Category	Configurable thresholds per user
Au	Actor, Action, Timestamp	Tamper-evident administrative log

Web Framework	Express.js 4.x
Database	MongoDB 6.x + Mongoose ODM
Authentication	JSON Web Tokens (jsonwebtoken)
Real-Time	WebSockets (ws library)
Frontend	Vanilla JS, HTML5, CSS3
Charts	Chart.js 4.x
RFID Hardware	RC522 / USB RFID + Mifare cards
Security	bcryptjs (salt rounds: 10)

Table I. ALTS Core Data Collections

The dataset grows continuously with system usage. A seed script populates demo users, shops, and transactions for testing purposes.

VII. METHODOLOGY

A. Limit Enforcement Logic

For each RFID scan event, the enforcement engine executes the following sequence:

15. Retrieve the user's active limit policy (daily and weekly thresholds in standardized units).
16. Aggregate all ALLOW-decision transactions within the current calendar day and ISO week.

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17. Compute the prospective post-purchase consumption for the current request.
18. If either the daily or weekly prospective total exceeds the configured threshold, issue DENY; otherwise, issue ALLOW.
19. Persist the decision and, for ALLOW, the full transaction record atomically.
20.

B. Authentication and Authorization

JWT tokens are issued upon successful credential validation. Each token carries a role claim (admin, shop, user) and a subject claim (MongoDB ObjectID). All API routes enforce role-based middleware guards, ensuring strict permission isolation between all three roles.

C. Real-Time Communication

The ws library establishes a persistent WebSocket server co- hosted with the Express HTTP server. The RFID reader client connects and emits UID events. The server processes each event synchronously within the enforcement engine and broadcasts the decision back to all authenticated shop dashboard clients subscribed to the relevant shop channel.

VIII. IMPLEMENTATION

A. Technology Stack

The complete technology stack is shown in Table II.Table II. ALTS Technology Stack

B. Project Structure

The codebase consists of 27 files: server.js (entry point), config/db.js (database connection), models/ (Mongoose schemas for User, Transaction, Shop, Policy), routes/ (Express routers for auth, admin, shop, user, rfid endpoints), middleware/ (JWT validation and role guards), public/ (static frontend assets per role), and scripts/seed.js (database seeder with demo credentials for all three roles).

C. Role-Based Dashboards

Each dashboard is served as a single-page application. The admin panel includes a system-wide transaction heatmap, per- user consumption bar charts, and a user management table with export. The shop panel features a large-format real-time ALLOW/DENY indicator, live scan log table, and a daily summary doughnut chart. The user panel shows a personal consumption gauge, weekly trend line chart, and paginated transaction history.

IX. RESULTS AND DISCUSSION

The system was tested across three evaluation dimensions: functional correctness, performance under load, and user experience.

A. Functional Correctness

All 47 defined test cases passed successfully. Limit enforcement was verified for edge cases including: transactions at exactly the threshold boundary, simultaneous scans from two users at the same shop, policy updates taking immediate effect on subsequent scans, and DENY decisions for suspended accounts.

B. Performance Metrics

Measured performance results against defined targets are shown in Table III.

Metric	Result	Target
RFID-to-Decision Latency (avg)	< 200 ms	< 500 ms
RFID-to-Decision Latency (p99)	< 450 ms	< 1000 ms
Concurrent Users Supported	50+	20
Transaction Write Success Rate	99.97%	99.9%

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Dashboard Render Time (initial)	< 800 ms	< 2000 ms
JWT Validation Overhead	< 2 ms	< 10 ms

Component	Technology
Runtime	Node.js v18 LTS

Table III. ALTS Performance Metrics

C. Discussion

The sub-200 ms average RFID-to-decision latency ensures no perceptible delays at the point of sale. The WebSocket-based communication architecture was central to achieving this, eliminating the round-trip overhead inherent in polling-based alternatives. MongoDB's document model proved well-suited to heterogeneous user profiles and transaction metadata. The role-based JWT architecture successfully isolated administrative, shop-operator, and end-user permissions throughout all test scenarios.

ADVANTAGES

- Real-time, sub-second enforcement decisions at point of sale via WebSocket communication.
- Complete tamper-evident audit trail with UTC- timestamped, immutable transaction records.
- Configurable limit policies supporting both individual and group-level thresholds.
- Three-tier role-based access control ensuring data isolation between all user types.
- Lightweight vanilla JavaScript frontend requiring no build toolchain for rapid deployment.
- Scalable Node.js backend handling concurrent WebSocket and REST API requests on commodity hardware.

X. LIMITATIONS

- Physical RFID hardware reliability: Card demagnetization or reader failures can disrupt service without failover infrastructure.
- Consumption outside the system: Limits are enforced only at registered RFID-enabled shops; off-system purchases remain untracked.
- Single-factor RFID authentication: Card sharing or loss is undetected without supplementary biometric verification.
- Offline operation: The current implementation requires continuous network connectivity between the reader and backend.

XI. FUTURE WORK

- AI/ML integration: Predictive behavioral analytics using LSTM models to identify at-risk consumption trajectories and trigger proactive interventions.
- Biometric augmentation: Combining RFID with fingerprint or facial recognition to prevent card-sharing fraud.
- Mobile application: Native iOS and Android apps for self- monitoring, history viewing, and push notifications when approaching limits.
- Offline resilience: Local queue buffering on the RFID reader hardware with automatic synchronization on network reconnection.
- Government integration: Connecting ALTS to national alcohol licensing databases for cross-outlet limit enforcement.
- Advanced analytics: Heatmap visualization, cohort analysis, and policy effectiveness dashboards for health administrators.

XII. CONCLUSION

This paper presented the Alcohol Limitation and Tracking System (ALTS), a full-stack, RFID-integrated web platform for automated alcohol purchase monitoring and enforcement. By combining RFID-based user identification with a Node.js/Express.js backend, MongoDB data persistence, WebSocket real-time communication, and role-differentiated JavaScript dashboards, ALTS delivers a practical, scalable, and cost-effective solution to uncontrolled alcohol distribution in regulated environments.

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The system successfully enforces configurable per-user consumption limits with sub-200 ms decision latency, maintains comprehensive audit logs, and provides actionable analytics to all three user roles. Experimental evaluation confirmed functional correctness across all test scenarios and performance within defined targets under concurrent load. ALTS demonstrates that the convergence of commodity RFID hardware, modern web technologies, and event-driven backend architectures can produce a system capable of meaningful real- world impact in public health and responsible consumption management.

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