

# End-To-End Biometric-Integrated Canteen and Feedback Analytics System

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**Abstract**--The digitalization of institutional facilities provides a critical opportunity to automate and optimize essential services such as canteen management. This paper proposes a comprehensive Smart Canteen Management System utilizing Internet of Things (IoT) technologies and modern web frameworks to address inefficiencies in traditional, manual token-based systems. The proposed architecture integrates real-time biometric attendance tracking via ESSL devices, automated meal token generation using ESC/POS thermal receipt printers, and barcode validation. Built upon an ASP.NET Core REST API backend and a responsive React-based frontend dashboard, the solution incorporates role-based access control, ensuring high data integrity and security. To ensure high service quality, a digital feedback module enables continuous monitoring of employee satisfaction and contractor performance. Furthermore, the system drastically reduces manual intervention, prevents meal fraud, and provides critical analytics for forecasting demand and minimizing food wastage. Experimental deployment and pilot testing demonstrate high reliability, fast token generation, and secure data logging, indicating a highly scalable architecture suitable for implementation in diverse institutional environments.

**Index Terms**--Smart Canteen, IoT Integration, Biometric Attendance, Role-Based Access Control

## I. INTRODUCTION

The fast growth of digital transformation initiatives has resulted in the installation of automated systems in a wide range of industries like healthcare, smart homes, manufacturing, and education. While this connectivity provides tremendous convenience, essential institutional operations like canteen management frequently remain reliant on outdated, manual processes. Canteens serve hundreds or

thousands of individual's daily, generating massive operational data regarding food consumption, attendance, and financial billing.

Traditional canteen systems utilize physical paper tokens or manual ledger entries, which are highly error-prone and easily subjected to fraudulent activities, such as proxy token collection and unauthorized meal redemptions. Furthermore, the inability to accurately predict meal demand based on real-time attendance leads to significant food wastage, inflicting financial losses upon contractors and institutions.

To address these issues, this paper introduces a modern, centralized Smart Canteen Management System. By leveraging IoT devices—namely biometric attendance machines and thermal barcode printers—integrated with a robust ASP.NET Core backend and React frontend, the system fully automates meal token generation, enforces role-based security, and captures real-time feedback, establishing a transparent and efficient ecosystem for canteen administration.

## II. LITERATURE REVIEW

Literature shows a growing emphasis on utilizing IoT and digital platforms to provide improved management in institutional settings. Several methodologies address fragmented operations, but comprehensive integrations remain scarce.

### 2.1 REVIEW OF LITERATURE

#### 2.1.1 IoT in Institutional Canteens

There have been experiments utilizing RFID and barcode technologies to track student and employee meal attendance. These architectures confirm that

digital tokens significantly reduce queuing times [2]. However, most studies focus solely on payment gateways rather than holistic attendance-linked food distribution.

#### 2.1.2 Biometric Authentication and Time-Attendance Logging

Biometric verification systems, notably fingerprint and facial recognition integrations via ZKTeco / ESSL devices, have proven highly resilient against identity spoofing. Integrating these systems directly into auxiliary facilities ensures absolute synchronization between physical campus presence and meal eligibility[1].

#### 2.1.3 Data Visualization for Operational Management

Current systems increasingly adopt modern JavaScript frameworks (like React or Angular) integrated with charting libraries to provide real-time dashboards. Real-time data streaming via WebSockets (e.g.,SignalR) has been demonstrated to provide crucial live-monitoring capabilities that batch-processing systems lack

### III. PROBLEM STATEMENT

With the rampant expansion of institutional headcounts, tracking individual meal consumption and reconciling contractor billing manually has become increasingly unsustainable. But this manual tracking leads to severe discrepancies. Without real-time attendance integration, canteen contractors prepare meals based on rough estimates, leading to either food shortages or massive wastage. Furthermore, the absence of an auditable digital trail allows for meal token duplication, resulting in financial leakages. Finally, employees lack an anonymous and structured medium to provide feedback on food quality, leaving administrators without data-driven insights to evaluate contractor performance.

### IV. OBJECTIVE

The main aim of this study is to create and deploy a comprehensive, IoT-integrated Smart Canteen Management System. The primary objectives are: To eliminate manual coupon systems by automating physical meal token generation via biometric and smart card validation.

To integrate live employee attendance data with the canteen distribution system to optimize food production and decrease wastage.

To gather, analyze, and visualize employee feedback securely to improve long-term canteen service quality. To implement role-based access control (RBAC), securing sensitive financial reports and unit-wise analytics for authenticated administrators and HR personnel.

### V. EXISTING SYSTEM

Existing canteen management mechanisms generally follow isolated designs in which coupons are pre-printed and manually distributed by administrative staff at the start of the month. Employees hand over physical paper coupons to counter staff in exchange for a meal. At the end of the day or month, these coupons are physically counted to calculate contractor payments. Some marginally upgraded systems utilize standalone Point-of-Sale (POS) terminals that scan static barcode ID cards, but these perform no real-time validation against daily attendance systems.

#### 5.1 LIMITATIONS OF THE EXISTING SYSTEM

Despite their widespread use, current canteen systems suffer from several fundamental limitations. First, physical coupons are easily lost, duplicated, or shared among unauthorized individuals, leading to fraudulent billing. Second, independent POS systems lack connectivity to central HR attendance databases, meaning an employee marked absent can theoretically still redeem a meal using a proxy ID. Most importantly, existing setups provide no real-time dashboard for proactive monitoring, compelling administration to rely on delayed, end-of-month printed reports.

### VI. PROPOSED SYSTEM

The suggested system presents an interconnected, multi-tier software and hardware architecture tailored for automated canteen environments to mitigate the shortcomings of conventional workflows. The system incorporates ESSL biometric terminal integration over TCP/IP, automatically fetching employee check-in statuses via a continuous background worker service. Once an employee is verified, the system triggers network-enabled thermal printers via the ESC/POS

protocol to instantly print a single-use Barcoded Meal Token containing a cryptographic timestamp. This token is subsequently scanned at the serving counter, eliminating proxy redemptions. The backend is constructed using ASP.NET Core (.NET 10), communicating over secure REST API endpoints protected by JSON Web Token (JWT) authorizations. The data flow culminates in a real-time React-based Web Dashboard utilized by administrators to monitor live token generation, view shift-wise consumption analytics, and scrutinize unit-wise feedback ratings. This combination of IoT automation and web-based data visualization offers a scalable, transparent, and efficient operational infrastructure..

### VII. SYSTEM ARCHITECTURE

The system architecture for the Smart Canteen Management System is designed to provide a scalable, modular, and secure infrastructure. It follows a three-tier architecture pattern separating IoT hardware, backend services, and frontend visualization. The architecture consists of three main layers:

- IoT Hardware Layer: ESSL biometric machines, thermal printers, barcode scanners connected via LAN.
- Backend API Layer: ASP.NET Core REST API, .NET Worker Service for biometric polling, SQL Server database, SignalR hub.
- Frontend Dashboard Layer: React 18 admin panel with analytics, reports, feedback, and RBAC

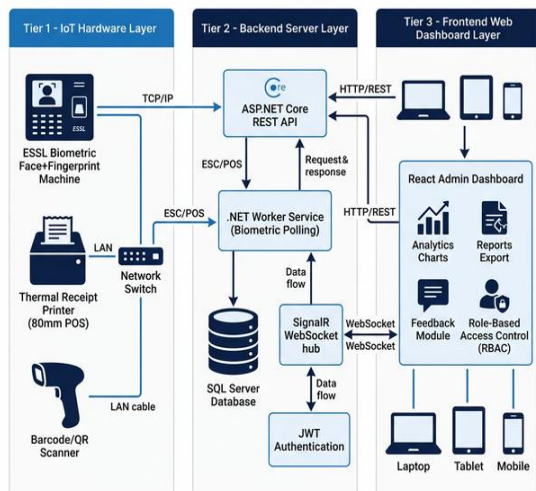


Fig. 7.1 Architecture

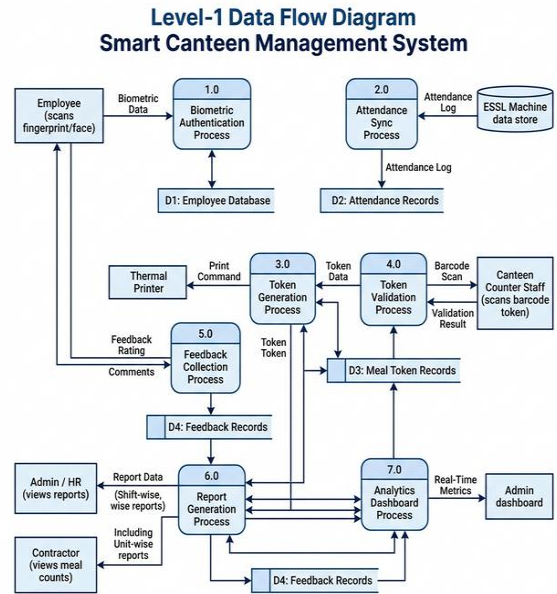


Fig. 7.2 DFD

### VIII. METHODOLOGY ADOPTED

The Smart Canteen Management System adopts an Agile-inspired iterative development methodology designed to handle the integration complexities between IoT hardware and web-based software architectures. This methodology ensures continuous testing, immediate feedback, and high adaptability to changing institutional requirements. The entire lifecycle is divided into the following sequential and overlapping phases:

#### 8.1. Requirement Gathering & Analysis Phase:

During this initial phase, the core operational pain points of the existing manual canteen system were identified. Detailed discussions were held with administrative staff, HR, and canteen contractors to define critical requirements such as biometric attendance integration, real-time demand forecasting, role-based access control, and feedback collection.

#### 8.2. System Design Specification Phase:

Based on the collected requirements, comprehensive system blueprints were drafted. This includes defining the exact architectural framework (Three-Tier Architecture), designing the underlying Entity-Relationship (ER) model for the SQL database, and laying out the Unified Modeling Language (UML)

diagrams (Class, Sequence, Activity, Data Flow) to map the interaction between the ESSL biometric devices, the .NET backend API, and the React frontend.

### 8.3. Hardware & Software Integration Prototyping Phase:

Instead of delayed integration, an early prototyping approach was taken. A localized test environment was established consisting of an ESSL i-Face terminal and an 80mm thermal receipt printer. The .NET Worker Service was coded to poll the biometric SDK over TCP/IP, and the raw ESC/POS byte commands were successfully tested for instant receipt printing, validating the core technical feasibility of the project.

**Sprint 1 (Backend Core):** Developing the ASP.NET Core REST API, configuring Entity Framework database migrations, and setting up JWT authentication.

**Sprint 2 (Frontend Dashboard):** Building the React-based admin panel, integrating Tailwind CSS for responsiveness, and setting up Recharts for shift-wise analytics.

**Sprint 3 (Real-Time Comm):** Integrating SignalR to push live WebSocket events to the dashboard whenever a token is printed at the canteen entry.

### 8.4. Comprehensive Testing Phase:

A multi-layered testing strategy was implemented. Unit tests validated individual API endpoints via Postman. Integration testing ensured seamless data flow from the biometric scanner to the thermal printer and database. Finally, Whitebox and Blackbox testing methods were applied to evaluate role-based access restrictions and system behavior under simulated heavy traffic loads.

### 8.5. Deployment & User Acceptance Phase:

The finalized build was hosted locally on an IIS Windows Web Server. The system was exposed to a pilot group (administrators and select employees) to gauge User Acceptance Testing (UAT). Based on their feedback, minor adjustments to the UX flow and data export formats (Excel/PDF) were incorporated before signing off on the finalized stable release.

## IX. SYSTEM IMPLEMENTATION

The implementation of the Smart Canteen Management System involves the development and integration of five core software modules, each handling a specific functional domain. The system follows a modular, microservices-inspired architecture pattern to cleanly separate IoT hardware polling, backend API logic, and frontend rendering.

### 9.1. Module Names:

- User Authentication Module
- Biometric IoT Registration & Polling Module
- Token Generation & Thermal Printing Module
- Analytical Admin Dashboard Module
- Employee Feedback & Rating Module

### 9.2. Module Descriptions:

**User Authentication & RBAC Module:** Utilizes ASP.NET Identity and JWT to authenticate users. Each user is assigned specific roles (Admin, HR, Contractor, Viewer). The API natively blocks unauthorized endpoints, ensuring strict data segregation and privacy.

**Biometric IoT Registration Module:** A background .NET Worker Service utilizes TCP/IP SDKs to constantly poll campus ESSL fingerprint/face recognition devices. Attendance logs are ingested and mirrored into the centralized SQL database instantly.

**Token Generation Module:** Upon successful biometric validation at the canteen entry, the system evaluates the current time-shift (Breakfast, Lunch, Dinner). It then transmits ESC/POS raw byte commands via TCP to an 80mm thermal receipt printer, dispensing a time-stamped barcode token.

**Analytical Admin Dashboard Module:** Built with React and TailwindCSS, this dashboard visualizes real-time metrics. Managers can export historical unit-wise and shift-wise consumption reports to Excel or PDF for standardized billing and audits.

**Employee Feedback & Rating Module:** Provides a secure digital portal for employees to submit food quality ratings and comments post-meal. The data is securely stored and aggregated on the React dashboard, enabling continuous service evaluation and alerting administrators to persistent negative trends in localized canteen units.

X. RESULT AND DISCUSSION

The proposed system was rigorously tested using simulated and localized hardware environments consisting of an ESSL i-Face terminal and a TVS thermal printer connected over a local gigabit network. The token generation module, powered by a localized .NET Worker Service, recorded sub-second response times between biometric identification and thermal printer actuation, guaranteeing smooth queue management during peak hours.

By employing SignalR, the web dashboard reflected token generation and redemption events instantly without requiring browser page refreshes. During load testing, simulating hundreds of simultaneous network requests, the ASP.NET Core backend maintained high throughput with minimal CPU overhead.

In conclusion, the system demonstrates a highly practical integration of hardware and software designed to eliminate traditional canteen fraud. The precise syncing of attendance protocols with digital token records ensures zero discrepancies in monthly contractor invoices. Defense in smart environments.

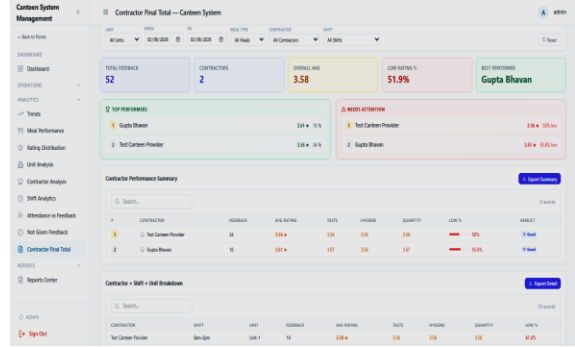


Figure10.3 Feedback Analysis

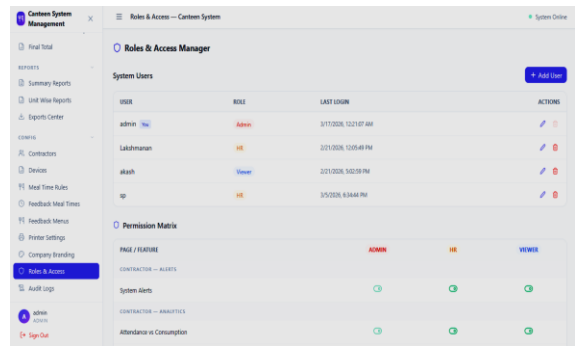


Figure10.4 Roles and Permissions

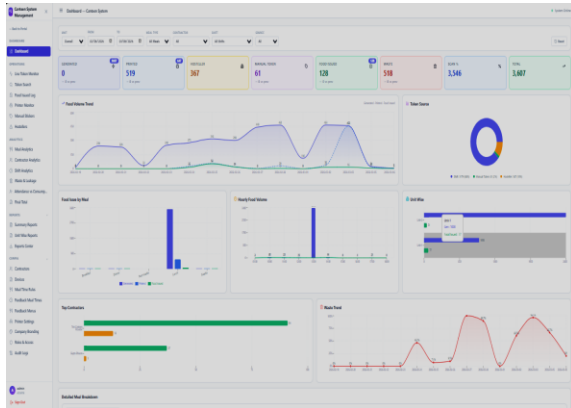


Fig. 10.1 Pricing

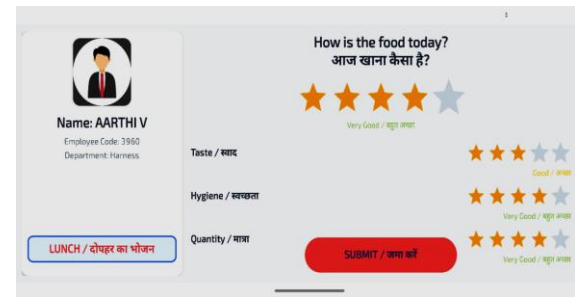


Fig. Review

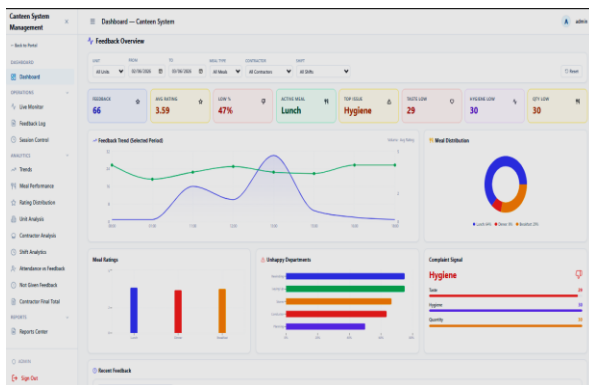


Fig. 10.2 Feedback System

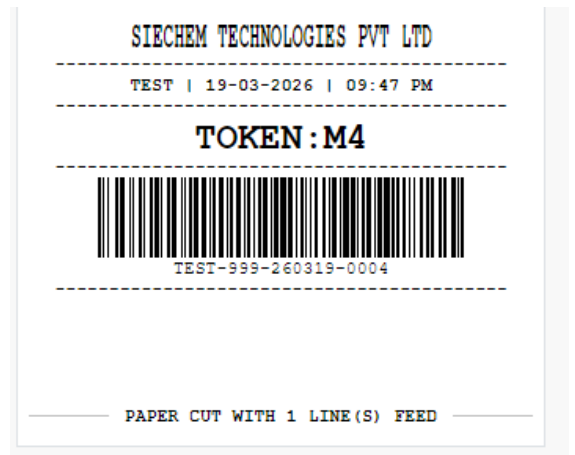


Figure10.6 Token Print

## XI. CONCLUSION

The combination of IoT edge hardware and modern centralized web frameworks offers a revolutionary method to optimize institutional resource management. This paper suggested and successfully deployed a Smart Canteen Management System to streamline user authentication, food tracking, and administrative oversight.

By utilizing ESSL biometric polling and automated thermal token printing, the system was able to reduce manual queue times and entirely eliminate physical coupon fraud. The React-based dashboard and .NET Core API enabled live operational analysis, securely regulated by rigid role-based mechanisms, making the solution technically robust and highly scalable.

The suggested system highlights a realistic and highly effective design for institutional security and resource optimization, ultimately minimizing food wastage and elevating the collective dining experience.

## XII. FUTURE SCOPE

The Smart Canteen Management System provides a robust platform for solving data integrity problems in institutional food distribution. One of the directions that looks promising is adopting machine learning algorithms (e.g., Time Series Forecasting) to analyze historical consumption data accurately predicting future daily meal demands, further driving down food wastage.

Another area of improvement is integrating a mobile application gateway. Allowing employees to pre-book meals remotely, view specific daily menus, and submit instant feedback through their smartphones would vastly enrich the user experience.

Lastly, integrating autonomous digital payment gateways—such as UPI, RFID payment bands, or automated salary deduction ledgers—will enable the system to process non-subsidized extra meal purchases securely. The potential for scaling and commercializing this model across regional educational campuses is enormous.

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