# A Modern Approach to Bus Pass Management Using Cloud Computing

L. Mani Yadav[1], Mr. P. Krishna Prasad[2]
[1]*Department of Master of Computer Applications, Chaitanya Bharathi Institute of Technology (Autonomous), Hyderabad, Telangana, India*
[2]*Guide, Assistant Professor, Department of MCA, Chaitanya Bharathi Institute of Technology (Autonomous), Hyderabad, Telangana, India*

***Abstract*—The increasing adoption of cloud computing has created opportunities to improve the efficiency, accessibility, and scalability of digital public services. Traditional bus pass management systems often depend on manual procedures involving physical applications, document submission, administrative approval, and renewal processes. These activities can result in delays, increased administrative workload, and inconvenience for passengers. This paper presents a modern cloud-based bus pass management system that simplifies the application and renewal process through a web-based platform. The proposed system enables users to register, submit bus pass applications, renew existing passes, complete payment procedures, and access digital bus passes. It incorporates QR code-based pass generation and verification to support convenient validation during travel.**

**An automated email notification mechanism is also included to remind users before their bus passes expire. Furthermore, the system incorporates cloud computing techniques, including the Round-Robin Load Balancing Algorithm for distributing incoming requests, AES-256 Encryption for protecting sensitive user information, and Consistent Hashing for efficient data distribution across distributed storage systems. The application is developed using web technologies and cloud-based storage and hosting services. Functional testing demonstrates the operation of the major modules, including registration, login, application submission, administrative approval, payment processing, QR code generation, and pass verification. The system provides a centralized and convenient approach to bus pass management while supporting improved accessibility, data protection, and operational efficiency.**

***Index Terms*—Cloud Computing, Bus Pass Management, QR Code, Round-Robin Load Balancing, AES-256 Encryption, Consistent Hashing, Web Application.**

## I. INTRODUCTION

Cloud computing has become an important technology for developing modern applications by providing flexible computing resources, centralized data management, and internet-based accessibility. It enables organizations to store, process, and manage information without depending entirely on traditional local infrastructure. These capabilities make cloud computing suitable for applications that require efficient data handling, accessibility, and scalability.

Public transportation plays a significant role in everyday urban mobility. Bus passes provide passengers with an affordable and convenient way to travel regularly. However, traditional bus pass management procedures generally involve visiting physical counters, completing application forms, submitting documents, and waiting for administrative approval. The renewal process may also require passengers to repeat several manual steps, resulting in inconvenience and unnecessary delays.

To overcome these limitations, a cloud-based bus pass management system is developed to automate the major operations associated with bus pass services. The system provides a web-based interface through which passengers can register, apply for new bus passes, renew existing passes, and access their pass information. Administrators can manage applications and perform the required approval operations.

The system also introduces QR code-based digital bus passes, allowing pass information to be accessed and verified conveniently. Automated email notifications inform users about upcoming pass expiration dates, helping them complete renewal procedures on time. In addition, Round-Robin Load Balancing, AES-256

Encryption, and Consistent Hashing are incorporated to address request distribution, information security, and distributed data management.

## II. RELATED WORK

Cloud computing has been widely investigated as a technology for improving application scalability, data storage, and service accessibility. Mell and Grance [1] presented the National Institute of Standards and Technology definition of cloud computing, describing its essential characteristics and service models. Their work provides a foundation for understanding cloud-based application development and resource management.

Armbrust et al. [2] discussed the opportunities and challenges associated with cloud computing. Their research highlighted the potential of cloud infrastructure to provide scalable computing resources and reduce the need for organizations to maintain extensive physical infrastructure. Buyya et al. [3] explored cloud computing as an emerging IT platform and discussed its role in delivering computing resources as a utility.

In transportation services, digital applications can simplify ticketing and passenger-related operations. QR code-based digital identification provides a convenient mechanism for retrieving and validating information. Bus pass management requires the integration of passenger registration, application submission, administrative approval, payment processing, pass generation, verification, and renewal notifications. The proposed system combines these operations with cloud computing techniques in a centralized platform.

## III. RESEARCH GAP AND PROBLEM FORMULATION

### A. Problem Statement

Traditional bus pass management systems involve several manual operations that create difficulties for passengers and administrative staff. Users may need to visit service counters to submit applications, provide information, complete payment procedures, and renew their passes. These processes can increase waiting time and administrative workload. Manual record maintenance can also make information retrieval and verification difficult. Physical bus passes require additional handling, while users may forget to renew their passes before expiration.

Therefore, a centralized cloud-based solution is required to automate the major bus pass operations while improving accessibility, security, and service efficiency.

### B. Objectives

- To develop a web-based platform for online bus pass applications and renewals.
- To simplify passenger registration and administrative approval.
- To generate QR code-based digital bus passes and support verification.
- To automate email notifications before pass expiration.
- To distribute incoming requests using Round-Robin Load Balancing.
- To protect sensitive information using AES-256 Encryption.
- To support data distribution using Consistent Hashing.

## IV. PROPOSED SYSTEM ARCHITECTURE

The proposed bus pass management system is designed as a cloud-based web application consisting of multiple interacting modules. Passengers and administrators interact with the application through a web interface. User requests are sent to the cloud platform, where request distribution and application processing take place. The services layer handles authentication, pass management, QR code generation and verification, notifications, and administrative tasks. User details, pass information, and related records are maintained in the data layer.

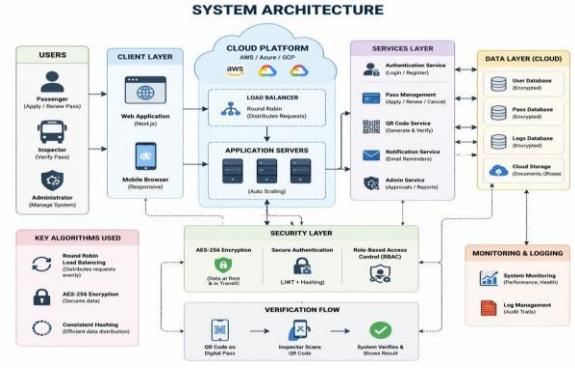


Fig. 1. System architecture of the proposed cloud-based bus pass management system.

The architecture incorporates a Round-Robin load balancer to distribute requests across available application servers. AES-256 encryption is specified for protecting sensitive information, while Consistent Hashing supports data distribution across distributed storage systems. The QR code verification process allows inspectors or conductors to scan digital passes and validate the associated pass information.

A. Use Case Diagram

The use case diagram represents interactions between the system and its actors. Passengers can register or log in, apply for or renew a pass, make payments, view routes, and display their QR pass. Conductors verify passes, while administrators verify applications and manage users and routes. The payment gateway supports payment processing.

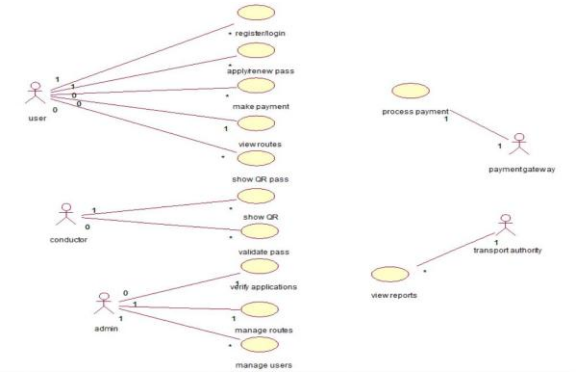


Fig. 2. Use case diagram showing passenger, conductor, administrator, and payment interactions.

B. Class Diagram

The class diagram presents the principal entities and their relationships, including User, Admin, Bus Pass, Payment, QR Code, Route, and related service components. It provides a structural view of the system and the responsibilities assigned to its main classes.

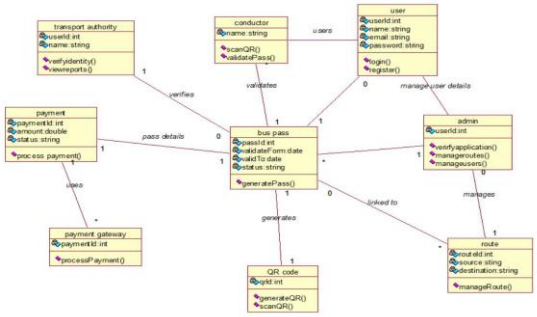


Fig. 3. Class diagram representing the principal bus pass management entities.

C. Sequence and Collaboration Diagrams

The sequence diagram illustrates the chronological interaction among the user, system, administrator, transport authority, payment gateway, and conductor. The collaboration diagram emphasizes the communication links and message exchanges among system objects during pass processing and verification.

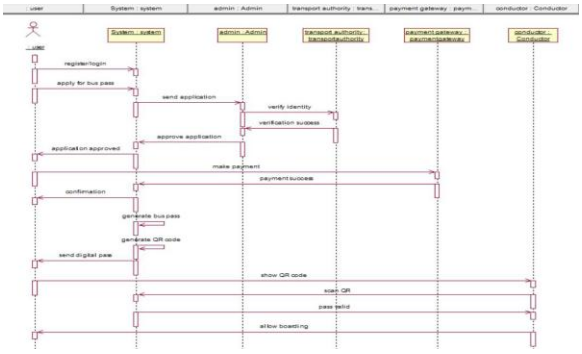


Fig. 4. Sequence diagram showing application, approval, payment, pass generation, and verification.

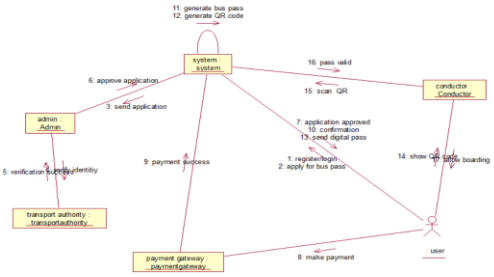


Fig. 5. Collaboration diagram showing communication among system objects.

D. Activity and Deployment Diagrams

The activity diagram describes the workflow from user registration and application submission through verification, approval, payment, pass generation, and subsequent use. The deployment diagram represents the placement of application components across user devices, web servers, databases, and supporting services.

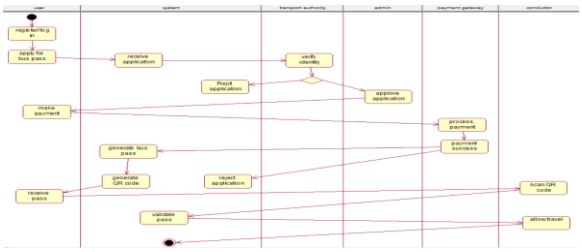

Fig. 6. Activity diagram illustrating the bus pass processing workflow.

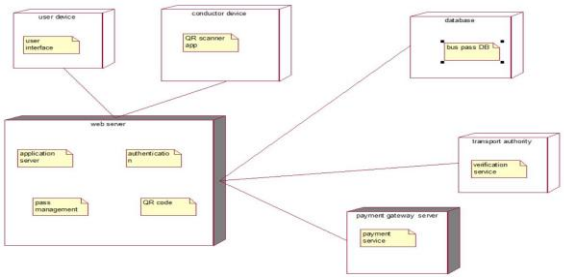


Fig. 7. Deployment diagram showing client, server, database, and supporting services.

## V. METHODOLOGY

### A. Round-Robin Load Balancing

Round-Robin Load Balancing is a scheduling technique that distributes incoming requests among available servers in a sequential manner. If three servers are available, requests are assigned in the order Server 1, Server 2, Server 3, and then the sequence repeats. This approach is intended to distribute the request load and improve resource utilization when multiple servers are available.

### B. AES-256 Encryption

Advanced Encryption Standard (AES) is a symmetric encryption algorithm. AES-256 uses a 256-bit key. In the proposed system, AES-256 is specified for protecting sensitive user information stored in the cloud environment. Encryption converts readable information into ciphertext, and decryption restores the original information using the appropriate secret key. Secure key management is necessary to maintain confidentiality.

### C. Consistent Hashing

Consistent Hashing is a technique for distributing data across multiple servers in a distributed storage environment. Servers and data items are mapped onto a logical hash ring. Each data item is assigned to the next available server according to the hashing order. When a server is added or removed, only a portion of the data needs reassignment, reducing data movement compared with conventional hash-based distribution.

## VI. IMPLEMENTATION

### A. Technology Stack

The project documentation specifies Node.js, JavaScript, and Express.js for the backend environment; HTML, CSS, JavaScript, and Bootstrap for the frontend; MySQL / MongoDB as the database options; Visual Studio Code as the development environment; and cloud-based storage and hosting services.

### B. Functional Modules

The registration and login module allows users to create accounts and access the application. The application and renewal module collects passenger and route details and submits requests for processing. The administrator module reviews applications and updates their status. The payment module supports payment processing. After successful processing, the digital pass generation module creates a QR code-based pass containing relevant passenger and validity information. The verification module supports scanning and validating the pass. The notification module sends email reminders before pass expiration.

### C. Application Interfaces

The following screenshots are taken from the implemented application as presented in the project documentation. They illustrate the user-facing workflow, from initial access and registration to application submission, payment, pass display, and QR code access.

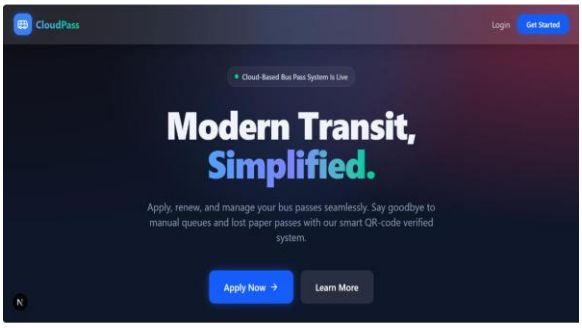


Fig. 8. Home page of the implemented bus pass management application.

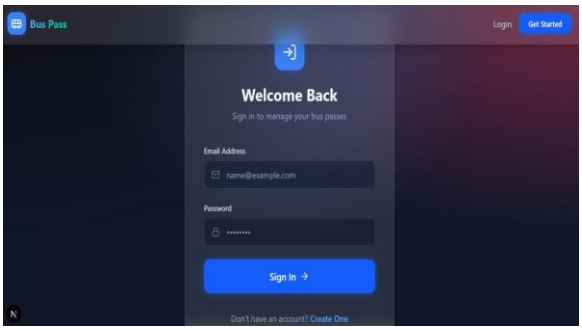


Fig. 9. User sign-in interface.




Fig. 10. User registration interface.

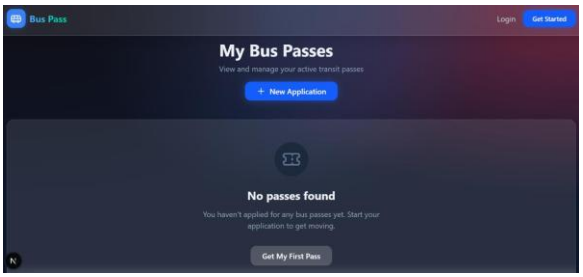


Fig. 11. Bus pass application interface.

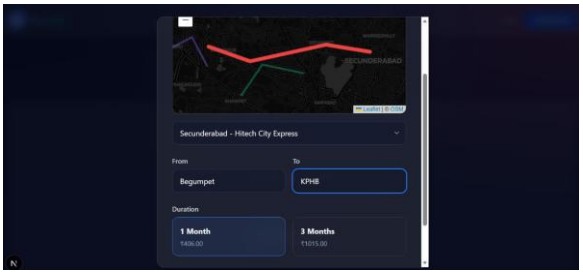


Fig. 12. Route selection interface.

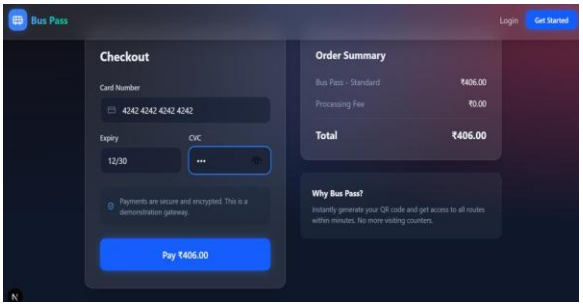


Fig. 13. Payment interface.

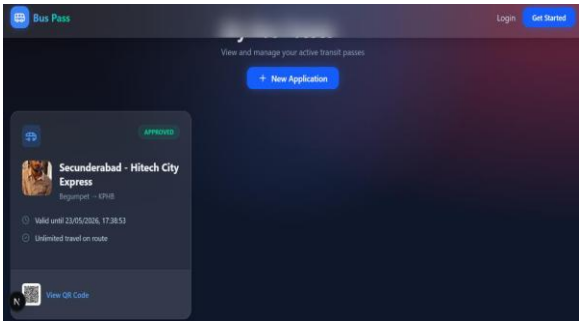


Fig. 14. Bus pass centre displaying the user's pass.

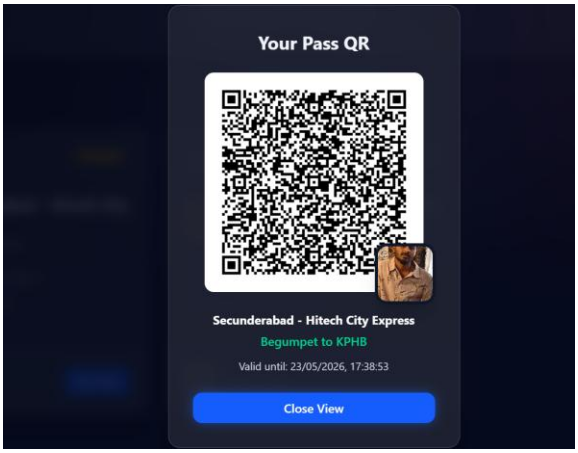


Fig. 15. QR code-based digital bus pass.




Fig. 16. QR code details and pass information.

## VII. TESTING AND RESULTS

The project was tested using scenarios covering user registration, login, bus pass application, payment processing, QR code generation, and pass verification. The documented results indicate that users can register and log in, applications remain pending until administrative approval, and approved users can proceed with payment and receive a QR code-based digital pass. The QR code and pass details are displayed through the application. The project documentation also reports automated email notifications before pass expiration.

| Test scenario | Expected outcome | Documented result |
|---|---|---|
| Registration and login | User account and access | Successful |
| Pass application | Application submitted | Successful |
| Admin approval | Application status updated | Successful |
| Payment processing | Payment workflow completed | Successful |
| QR generation | Digital pass generated | Successful |
| Pass verification | Pass information validated | Successful |
| Expiry reminder | Reminder email sent | Successful |

The available project report describes functional outcomes but does not provide numerical benchmark measurements for throughput, response time, encryption overhead, or large-scale load testing. Accordingly, this paper reports the documented functional behavior and does not claim measured percentage improvements or benchmark values.

## VIII. DISCUSSION

The proposed system combines bus pass application management with cloud computing techniques to provide a centralized digital platform. Online applications and renewals reduce dependence on physical service counters. QR code-based digital passes provide a convenient method for accessing and verifying passenger information. Automated email reminders help users identify upcoming expiration dates. The cloud techniques address different system concerns: Round-Robin Load Balancing supports request distribution, AES-256 Encryption is intended to protect sensitive information, and Consistent Hashing supports distributed data placement. Further quantitative testing would be required to evaluate performance under different workload and deployment conditions.

## IX. LIMITATIONS

The current system primarily focuses on web-based bus pass application and renewal. A dedicated mobile application for conductors and passengers, GPS-based real-time bus tracking, additional payment gateway and digital wallet options, mobile push notifications, and advanced analytics are identified as possible future enhancements. The available project documentation also does not provide numerical large-scale performance measurements.

## X. CONCLUSION AND FUTURE WORK

This paper presented a cloud-based bus pass management system designed to simplify passenger registration, application processing, renewal, payment, and digital pass verification. The system provides a web-based platform through which users can apply for new passes and renew existing ones. Administrative approval and payment processing support the application workflow, while QR code-based digital pass generation provides a convenient method of accessing and verifying pass information. Automated email notifications remind users before their passes expire.

The project incorporates Round-Robin Load Balancing for request distribution, AES-256 Encryption for protecting sensitive user information, and Consistent Hashing for data distribution across distributed storage systems. Functional testing demonstrates the operation of the major documented application modules. Future work may include dedicated mobile applications, GPS-based bus tracking, additional payment options, push notifications, analytics, and integration with other public transportation services.

## REFERENCES

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