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SmartQueue (QueueWise): A Real-Time Cloud-Based Queue Management System

Gauri Puranik[1], Madhushri Deshpande[2], Tanveersingh Bhamra[3], Prapti Bidve[4], Sayali Deshmukh[5]
[1,2,3,4,5] Department of Computer Engineering, Guru Gobind Singh College of Engineering & Research Centre, Nashik, India.
EmailID: *gauri.puranik@ggsf.edu.in[1], madhushry12@gmail.com[2], bhamratanveer00612@gmail.com[3], praptibidve18@gmail.com[4], sayali.k.deshmukh.2004@gmail.com[5].*

Abstract
The increasing demand for efficient service delivery in public and private sectors has highlighted the limitations of traditional queuing systems, such as overcrowding, long waiting times, and reduced productivity. This paper presents QueueWise, a real-time cloud-based queue orchestration platform designed to enable remote queue management and intelligent wait-time optimization. The proposed system allows users to monitor live queue status, join queues remotely, and schedule their arrival based on real-time progression. QueueWise is based on a hierarchical Organization–Event–Queue–Participant model, which ensures structured administration, scalability, and controlled access. The system incorporates real-time synchronization, automated lifecycle management, and predictive analytics to estimate waiting time accurately. Experimental results demonstrate that the proposed solution improves service efficiency, reduces physical congestion, and enhances user convenience. Overall, the system provides a scalable and user-centric approach to modern queue management.
Keywords: *Cloud computing; Predictive analytics; Queue management; Real-time systems; Smart queue.*

1. Introduction
The rapid growth of population and increasing demand for services in sectors such as healthcare, education, banking, and government institutions have made queue management a critical challenge. Traditional queuing systems require individuals to be physically present and wait in long lines, leading to overcrowding, time wastage, reduced productivity, and user dissatisfaction. These systems also lack transparency, as users have limited information about queue status, waiting time, and service availability [1]. With the advancement of digital technologies and cloud computing, there is a growing need for intelligent queue management systems that provide real-time updates and remote accessibility. Modern users expect convenience, flexibility, and efficient time utilization, which traditional systems fail to deliver. Additionally, service providers face challenges in managing crowd flow, optimizing staff utilization, and maintaining operational efficiency. Virtual queue management systems have emerged as a potential solution by enabling users to join queues remotely and monitor their status digitally [2]. However, many existing systems still lack real-time synchronization, predictive capabilities, and scalability required for dynamic environments. Recent research has focused on improving queue management using digital and intelligent techniques. A web-based virtual queue system proposed by Muskan et al. (2025) enabled remote registration, real-time tracking, and notification services, improving transparency and reducing waiting time. Deoraj et al. (2024) demonstrated the effectiveness of virtual queue systems in academic environments for reducing overcrowding and improving time management. Rajole (2022) developed an IoT-based queue management system that enhanced automation but faced scalability limitations due to hardware dependency. Mallari (2022) introduced a web-based queue system with real-time tracking and notifications, but it lacked predictive analytics capabilities [3]. Similarly, Soman (2020) proposed a mobile-based queue system that improved user convenience but faced

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challenges in large-scale environments. Earlier studies by Ngugi et al. (2019), Abusair and Sharaf (2018–2019), and Maulana et al. (2017) explored reservation-based and virtual queue systems, which reduced physical waiting but lacked real-time synchronization and adaptability. Ghazal et al. (2015) presented an IoT-based queue system with real-time tracking but faced scalability issues [4]. Recent industry trends indicate a shift toward cloud-based and AI-integrated queue systems, incorporating real-time analytics, mobile notifications, and predictive mechanisms to improve service delivery. However, existing systems still suffer from limitations such as lack of real-time synchronization, limited scalability, absence of accurate wait-time prediction, and inadequate support for hybrid queue handling. To address these challenges, this paper presents QueueWise, a real-time cloud-based queue orchestration platform designed to transform traditional queuing systems into smart and user-centric solutions. The system enables users to join queues remotely, track live queue progress, receive notifications, and plan their arrival efficiently. It also supports hybrid queue handling, staff availability tracking, and predictive wait-time estimation [5]. The proposed system aims to enhance user experience, reduce overcrowding, improve operational efficiency, and provide a scalable solution for modern service environments.

2. Method

The proposed work focuses on the design and implementation of QueueWise, a real-time cloud-based queue orchestration platform developed to improve queue management and optimize waiting time [6]. The methodology includes system design, data processing, system development, implementation, and performance evaluation.Tables and Figures are presented center, as shown below and cited in the manuscript.

2.1. System Design

QueueWise is designed using a hierarchical architecture consisting of four main levels: Organization, Event, Queue, and Participant. The Organization level represents service providers such as hospitals, banks, or institutions. Each organization can manage multiple events, where an event refers to a specific service session or activity. Within each event, multiple queues can be created to handle different services or categories. Participants represent users who interact with the system by joining queues and accessing real-time updates. This hierarchical structure ensures scalability and flexibility, allowing the system to manage multiple organizations and services efficiently. It also provides controlled access, enabling administrators to manage queues effectively while ensuring data consistency. The system architecture is illustrated in Figure 1. It illustrates the overall architecture of the QueueWise system. It represents the hierarchical structure consisting of Organization, Event, Queue, and Participant levels. This architecture ensures efficient data flow, scalability, and structured management of queue operations across different services.

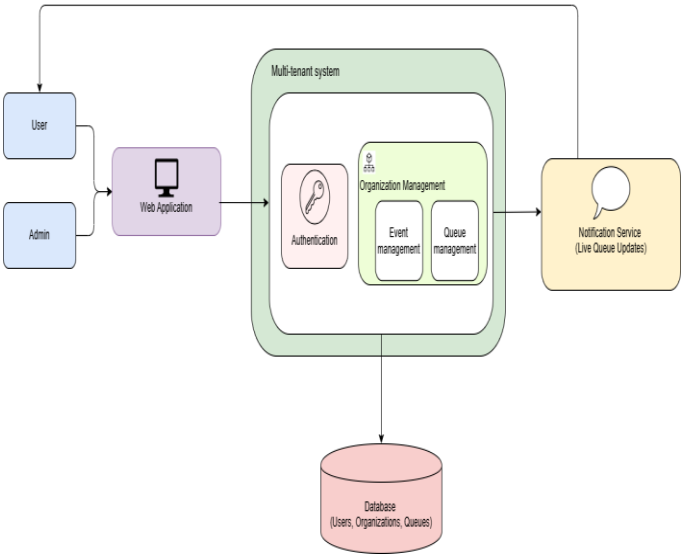

FIGURE 1 Queue Wise System Architecture

2.2. Data Processing

The system processes real-time queue data to maintain accuracy and synchronization across all users. When a user joins a queue, the system dynamically updates the queue state by recording the participant's position and estimated waiting time. The queue data is continuously updated based on service completion, new entries, and cancellations. The wait-time estimation is

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calculated using parameters such as queue length, service rate, and average handling time. This dynamic processing ensures that users receive accurate and up-to-date information, enabling them to plan their arrival efficiently [7]. Additionally, the system maintains data integrity through transactional updates, ensuring consistency in queue operations.

2.3. System Development

The QueueWise platform consists of multiple functional modules designed to enhance performance and usability. The real-time queue engine is responsible for managing queue operations, including entry, exit, and position updates. A notification module provides real-time alerts to users regarding queue progress and estimated waiting time [7]. A predictive analytics module is integrated into the system to estimate waiting time based on historical and real-time data. This module improves accuracy and enhances user experience. An administrative dashboard is also provided, allowing service providers to monitor queue status, manage participants, and control service flow efficiently. The system also supports hybrid queue management, enabling both walk-in users and scheduled appointments.

2.4. System Implementation

The QueueWise system is implemented using a modern web-based technology stack to ensure scalability, performance, and responsiveness. The frontend is developed using Next.js, which enables fast rendering and dynamic user interfaces. The backend is built using Express.js, which handles business logic, API requests, and queue operations efficiently [8]. MongoDB is used as the primary database due to its flexibility in handling dynamic data structures and scalability for large datasets. The system is deployed on cloud platforms, with the frontend hosted on Vercel and the backend deployed on Render. This deployment strategy ensures high availability, reliability, and efficient handling of multiple user requests. Communication between the frontend and backend is managed through RESTful APIs.

2.5. Performance Evaluation

The performance of the system is evaluated based on key parameters such as waiting time reduction, system response time, queue accuracy, and user satisfaction. These metrics help in assessing the effectiveness of the proposed solution compared to traditional queue management systems. The evaluation is conducted by simulating real-time user interactions and analyzing system performance under different load conditions.

3. Results And Discussion

The performance of the proposed QueueWise system was evaluated based on real-time efficiency, usability, and effectiveness in queue management. The evaluation was conducted by simulating multiple users interacting with the system simultaneously under different operational conditions.

3.1. Results

The system was tested in various scenarios, including multiple user participation, real-time updates, and queue processing operations. The results demonstrate that the system performs efficiently under dynamic conditions and provides accurate real-time updates to users. The performance metrics of the system are summarized in Table 1.

Table 1 System Performance Metrics

Parameter	Result
Waiting Time Reduction	40–60%
System Response Time	< 2 seconds
Real-Time Update Delay	< 1 second
Queue Accuracy	98%
User Satisfaction	High

The key performance metrics observed during testing include waiting time reduction, system response time, real-time update delay, and queue accuracy. The QueueWise system achieved a significant reduction in waiting time, ranging between 40% to 60%, compared to traditional queue systems [9]. The system response time was observed to be less than 2 seconds, ensuring a smooth and responsive user experience. Additionally, the real-time update delay was maintained below 1 second, allowing users to

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receive instant updates regarding their queue status. The system also achieved a queue accuracy of approximately 98%, indicating reliable queue position tracking and minimal inconsistencies. The system interfaces further demonstrate the effectiveness of the implementation. The event-level view allows users to access multiple services under a single organization [10]. The user interface displays real-time queue position and estimated waiting time, while the admin dashboard provides control over queue operations and participant management. The queue history dashboard enables analysis of service performance through recorded data. The system interface and functionality are further illustrated through various figures. Figure 2 shows the event-level interface, where multiple service events are organized under a single organization. This allows users to select specific services efficiently [11].

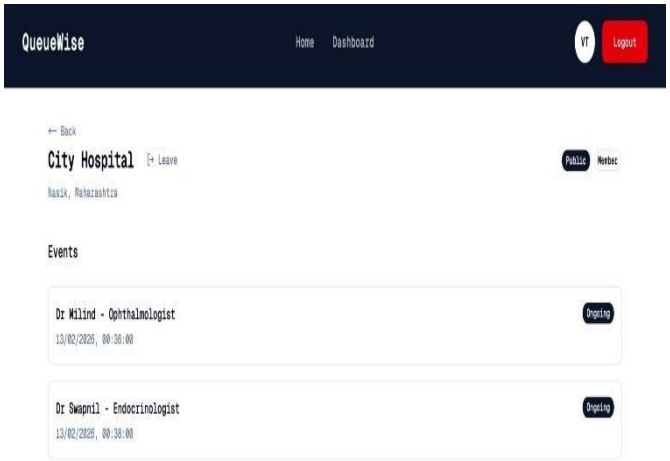

FIGURE 2 Event view

Figure 3 represents the user-side queue interface, which displays the current queue position and estimated waiting time. This interface enables users to monitor their status in real time and plan their arrival accordingly. It also provides a user-friendly layout with clear navigation options, ensuring ease of use for individuals with minimal technical knowledge [12]. The interface continuously updates queue information, reducing uncertainty and improving overall user experience.

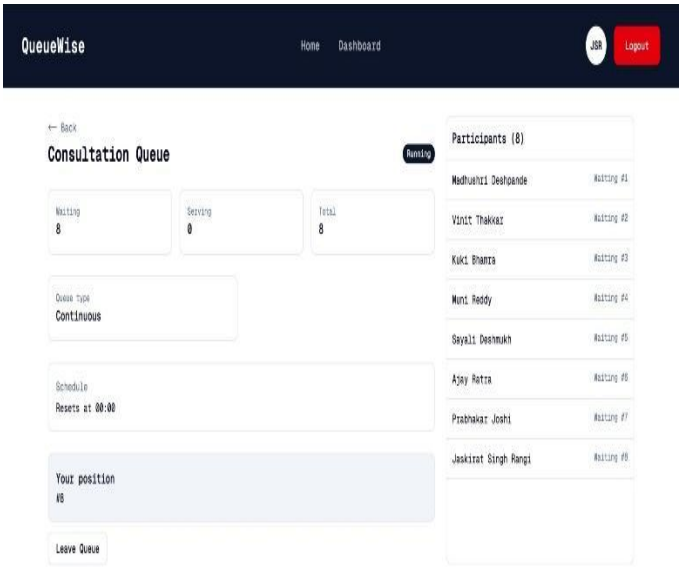

FIGURE 3 User interface

Figure 4 illustrates the admin dashboard, which provides real-time control over queue operations. It allows administrators to manage participants, update queue status, and ensure smooth service flow.

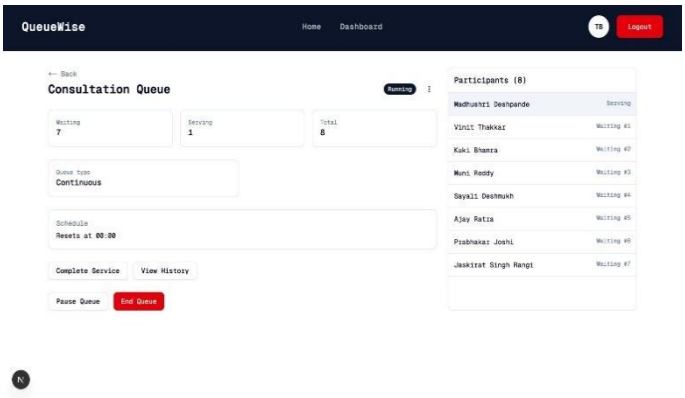

FIGURE 4 Admin dashboard

Figure 5 presents the queue history dashboard, which stores past records and performance metrics. This helps in analyzing service efficiency and improving decision-making based on historical data. The dashboard provides insights such as average waiting time, service duration, and queue trends over time. These analytics assist administrators in identifying bottlenecks and optimizing system performance for better service delivery [3]. Additionally, the historical

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data visualization enables comparison of past and present performance, helping in planning future improvements and resource allocation effectively.

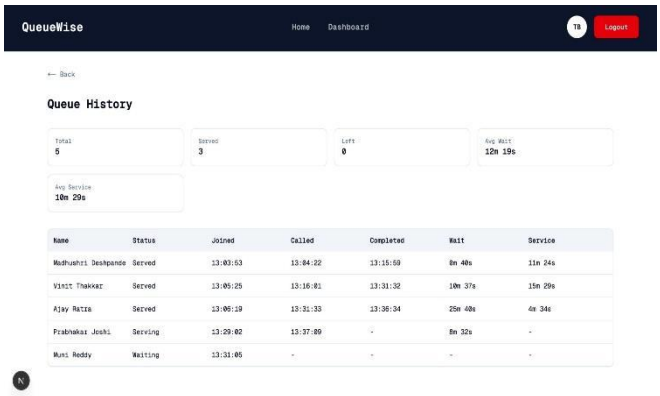

FIGURE 5 History dashboard

3.2. Discussion

The results clearly indicate that the QueueWise system provides a significant improvement over traditional queue management methods. The ability to join queues remotely reduces the need for physical presence, thereby minimizing overcrowding in service environments such as hospitals, banks, and government offices. The integration of real-time updates enhances transparency and allows users to plan their time more effectively. Unlike traditional systems, where users must wait without information, QueueWise provides continuous feedback regarding queue progress and expected waiting time. The predictive analytics component further strengthens the system by estimating waiting time based on real-time data. This feature improves user satisfaction by reducing uncertainty and enabling better decision-making [14]. The hybrid queue management approach, which supports both walk-in users and scheduled appointments, adds flexibility and improves system adaptability. From an administrative perspective, the system simplifies queue monitoring and management. Service providers can track queue status, manage participants, and optimize service flow using the admin dashboard. This leads to improved operational efficiency and better resource utilization. A comparative analysis between the traditional queue system and QueueWise highlights key advantages, including reduced waiting time, improved transparency, real-time updates, and predictive capabilities. Overall, the proposed system demonstrates strong performance and provides a scalable solution for modern queue management challenges.

Conclusion

This paper addresses the limitations of traditional queue management systems, such as long waiting times and lack of transparency. The proposed QueueWise system provides a real-time, cloud-based solution for efficient queue management and wait-time prediction. It enables users to join queues remotely, track real-time progress, and plan their time effectively. The experimental results demonstrate improved efficiency, reduced waiting time, and enhanced user experience. By integrating real-time synchronization and predictive analytics, the system ensures better service delivery. Overall, QueueWise offers a scalable and practical solution for modern service environments.

Future Scope

Future enhancements of QueueWise can focus on improving wait-time prediction using advanced machine learning techniques. The system can be further extended by developing mobile applications to enhance accessibility and user interaction, along with integrating location-based services to help users plan their arrival more efficiently. Features such as QR-based queue entry, voice assistant support, and multi-language interfaces can further improve usability and inclusivity. From a system architecture perspective, QueueWise can be evolved into a real-time, event-driven system to improve responsiveness and scalability. This can be achieved by integrating WebSocket based communication to enable instant updates between the server and clients, eliminating the need for continuous polling [15]. Additionally, Redis can be incorporated as an in-memory data store and message broker to support efficient event distribution and handle high concurrency.

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