iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 14 **Issue:** IV **Month of publication:** April 2026

DOI: https://doi.org/10.22214/ijraset.2026.78387

Real-Time City Bus Tracking System using GPS, Mobile Applications and Cloud Technologies: A Comprehensive Review

Prof. M. K. Nichat[1], Om S. Ghaysundar[2], Om S. Ghuse[3], Nikita Sontakke[4], Ajinkya Vairal[5], Pranjali Dhadase[6]
P. R. Pote Patil College of Engineering and Management

Abstract: Urban public transportation systems face significant challenges in providing reliable and transparent services to commuters. The absence of real-time information about bus locations leads to passenger uncertainty, inefficient journey planning, and reduced adoption of public transport. This review paper comprehensively examines the evolution, implementation methodologies, and technological frameworks of real-time city bus tracking systems. The study analyzes existing GPS-based tracking solutions, mobile application architectures, cloud computing integration, and emerging technologies including Internet of Things (IoT), Firebase Realtime Database, and machine learning prediction algorithms. Through systematic review of literature from 2018 to 2025, this paper identifies key technological components, implementation challenges, comparative analysis of existing systems, and future research directions. The findings reveal that modern bus tracking systems increasingly leverage cross-platform mobile frameworks like Flutter, cloud-based backend services, and predictive analytics to enhance user experience and operational efficiency.

Keywords: GPS System, Flutter, Firebase Console, Firestore Database, Google API.

I. INTRODUCTION

The rapid urbanization of cities worldwide has placed unprecedented pressure on public transportation infrastructure. According to the United Nations, approximately 55% of the global population resided in urban areas in 2018, with projections indicating this figure will reach 68% by 2050 [1]. This demographic shift necessitates efficient, reliable, and accessible public transportation systems. However, traditional bus transit systems often operate with fixed schedules that fail to account for real-time traffic conditions, unexpected delays, or route deviations, resulting in significant passenger inconvenience and reduced system efficiency [2].

The advent of Global Positioning System (GPS) technology, coupled with widespread smartphone adoption and cloud computing advancements, has created unprecedented opportunities for transforming public transportation through real-time tracking and information dissemination. Modern city bus tracking systems employ GPS-enabled devices installed in buses to continuously capture location data, which is then transmitted to cloud servers and made accessible to passengers through mobile applications [3]. This technological integration addresses fundamental challenges in public transportation: uncertainty regarding bus arrival times, inefficient route planning, and lack of transparency in service delivery.

A. Motivation and Problem Statement

The primary motivation for developing real-time bus tracking systems stems from the inherent inefficiencies in conventional public transportation. Passengers typically experience three critical pain points: unpredictable waiting times at bus stops, inability to plan journeys with confidence, and lack of real-time updates regarding delays or route changes [4]. These issues collectively contribute to reduced public transport adoption, increased private vehicle usage, and consequent urban congestion and environmental degradation.

Research conducted by Kumar and Singh demonstrated that implementing real-time bus tracking systems reduced average passenger waiting times by 35-45% and increased overall public transport ridership by 18-22% in metropolitan areas [5]. Furthermore, transit authorities benefit from enhanced fleet management capabilities, data-driven operational insights, and improved service quality monitoring [6].

B. Scope and Organization

This review paper systematically examines the technological landscape of real-time city bus tracking systems, focusing on GPS technology integration, mobile application development frameworks, cloud computing architectures, and emerging innovations in predictive analytics and IoT integration. The paper is organized as follows: Section II presents the fundamental technological components and architectural frameworks. Section III provides a comprehensive literature review of existing systems and research contributions. Section IV analyzes implementation methodologies and technological choices. Section V discusses challenges, limitations, and research gaps. Section VI explores future research directions and emerging technologies. Finally, Section VII concludes the paper with key findings and recommendations.

II. FUNDAMENTAL TECHNOLOGIES AND SYSTEM ARCHITECTURE

A. GPS Technology and Location Services

Global Positioning System technology forms the cornerstone of real-time bus tracking systems. GPS operates through a constellation of satellites that transmit signals enabling receivers to determine precise geographical coordinates through trilateration [7]. Modern GPS receivers integrated into smartphones and dedicated tracking devices achieve accuracy levels of 5-10 meters under optimal conditions, which proves sufficient for bus tracking applications in urban environments [8].

The implementation of GPS tracking in public transportation vehicles typically employs one of two approaches: dedicated GPS tracking devices installed in buses, or smartphone-based applications running on drivers' personal devices. Dedicated hardware solutions offer superior reliability and consistent power supply but incur higher initial costs and maintenance requirements. Conversely, smartphone-based solutions reduce infrastructure costs but introduce challenges related to battery consumption, application reliability, and device compatibility [9].

B. Mobile Application Frameworks

The proliferation of smartphones has made mobile applications the primary interface for passengers to access real-time bus tracking information. The selection of mobile application development framework significantly impacts development efficiency, application performance, user experience, and maintenance overhead [10]. Cross-platform frameworks, particularly Flutter developed by Google, have gained substantial traction in recent years. Flutter employs the Dart programming language and compiles to native code for both iOS and Android, delivering nearnative performance while maintaining a single codebase [11].

C. Cloud Computing and Backend Infrastructure

Cloud computing infrastructure serves as the intermediary layer between GPS-equipped vehicles and passenger-facing mobile applications. Cloud platforms provide scalable data storage, real-time data processing, user authentication, and API services essential for modern bus tracking systems [12]. Firebase, Google's comprehensive mobile and web application development platform, has emerged as a particularly popular choice for bus tracking systems due to its integrated services including Firebase Realtime Database, Cloud Firestore, Firebase Authentication, and Firebase Cloud Messaging [13].

D. System Architecture Models

Real-time bus tracking systems typically adhere to a three-tier architectural pattern comprising the presentation layer (mobile applications), application logic layer (backend services and APIs), and data layer (databases and storage) [14]. This separation of concerns enhances system maintainability, enables independent scaling of components, and facilitates technology stack modifications without affecting other layers. The dual-database approach combining relational databases like PostgreSQL or MySQL for structured data with NoSQL databases like Firebase or MongoDB for real-time location data has become standard practice [15].

III. LITERATURE REVIEW

A. Evolution of Bus Tracking Systems

The evolution of bus tracking systems can be categorized into three distinct generations, each characterized by technological advancements and increasing sophistication. First-generation systems, prevalent from the late 1990s to mid-2000s, relied on Automatic Vehicle Location (AVL) technology using GPS receivers in buses transmitting location data to central servers via cellular networks [16]. Second-generation systems, emerging around 2010-2015, introduced smartphone applications enabling passengers to access real-time bus locations through internet-connected devices. Third-generation systems, characterized by cloud computing integration, IoT technologies, and predictive analytics, have dominated since 2016 [17].

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 14 Issue IV Apr 2026- Available at www.ijraset.com

B. Comparative Analysis of Existing Systems

Table I presents a comprehensive comparison of notable bus tracking systems developed and deployed in recent years, analyzing their technological components, features, and reported performance metrics.

TABLE I
COMPARATIVE ANALYSIS OF RECENT BUS TRACKING SYSTEMS

System	Year	Technology Stack	Key Features	Accuracy	Reference
SmartBus India	2019	Android, PHP, MySQL	Real-time tracking, SMS alerts	85-90%	[18]
CloudBus System	2021	Flutter, Firebase, Google Maps	Crossplatform, Push notifications	88-93%	[19]
SmartCity Transit	2024	Flutter, Firebase, ML Kit	AI predictions, Voice interface	93-96%	[20]

The analysis reveals that cross-platform frameworks, particularly Flutter, have gained predominance over native development due to reduced development costs and maintenance overhead. Cloud-based backend solutions have largely replaced on-premises server infrastructure, with Firebase and AWS emerging as preferred platforms.

C. Arrival Time Prediction Algorithms

Accurate arrival time prediction represents a critical feature distinguishing advanced tracking systems from basic location reporting. Machine learning approaches have demonstrated superior performance in arrival time prediction. Regression models including Support Vector Regression (SVR), Random Forest, and Gradient Boosting have been successfully applied to predict arrival times based on historical data, current traffic conditions, time of day, and weather patterns [21]. Deep learning architectures, particularly Long Short-Term Memory (LSTM) networks, have shown promise in capturing temporal dependencies in bus movement patterns [22].

IV. IMPLEMENTATION METHODOLOGIES

A. Mobile Application Development

The implementation of passenger and driver mobile applications requires careful consideration of user experience design, performance optimization, and feature prioritization. Modern bus tracking applications typically include core features such as real-time bus location visualization on interactive maps, route search and selection, arrival time predictions, push notifications for bus arrivals, and user account management [23]. Performance optimization techniques are crucial for ensuring smooth user experience, particularly on lower-end devices.

B. Backend System Architecture

Backend system design must address scalability, reliability, real-time data processing, and security requirements inherent to bus tracking applications. Microservices architecture has emerged as the preferred approach, decomposing monolithic applications into specialized services including authentication service, location processing service, notification service, route management service, and analytics service [24].

C. Security and Privacy Considerations

Security and privacy concerns in bus tracking systems encompass user data protection, location data privacy, API security, and compliance with data protection regulations including GDPR and CCPA [25]. Location data privacy represents a particularly sensitive concern. Implementation should avoid collecting or storing individual passenger locations, instead focusing solely on vehicle positions.

V. CHALLENGES AND RESEARCH GAPS

Despite significant advances in bus tracking technologies, several technical challenges persist. GPS signal degradation in urban canyons, tunnels, and areas with dense overhead structures limits tracking accuracy and reliability. Battery consumption represents a critical concern for smartphone-based driver applications performing continuous GPS tracking and data transmission. Network connectivity variability impacts real-time data transmission reliability.

Identified research gaps include predictive analytics for proactive service optimization, energyefficient tracking algorithms minimizing battery consumption, passenger load prediction and crowding management, and multi-modal transportation integration algorithms optimizing entire journeys across buses, trains, shared mobility services, and active transportation.

VI. FUTURE DIRECTIONS AND EMERGING TECHNOLOGIES

The integration of advanced AI and machine learning technologies promises to transform bus tracking from passive information systems into intelligent predictive platforms. Deep reinforcement learning approaches could optimize entire transit networks by learning optimal policies for vehicle dispatch, route adjustments, and resource allocation based on real-time conditions. Comprehensive IoT sensor integration extends tracking systems beyond simple location reporting, with environmental sensors monitoring air quality, noise levels, and temperature inside buses.

The deployment of 5G cellular networks promises transformative improvements in tracking system capabilities through ultra-low latency, high bandwidth, and massive device connectivity. Environmental sustainability considerations are increasingly influencing tracking system design, with energy harvesting technologies including solar panels on bus roofs and kinetic energy recovery systems powering tracking devices.

VII. CONCLUSION

This comprehensive review has examined the current state of real-time city bus tracking systems, analyzing technological foundations, implementation methodologies, existing research, challenges, and future directions. The findings reveal that modern tracking systems have evolved significantly from early GPS-based solutions into sophisticated platforms integrating cloud computing, mobile technologies, IoT sensors, and artificial intelligence.

Key technological trends include the dominance of cross-platform mobile frameworks, particularly Flutter, offering development efficiency without sacrificing performance; widespread adoption of cloud-based backend infrastructures, especially Firebase and AWS; integration of machine learning algorithms for arrival time prediction achieving accuracy levels above 90%; and growing emphasis on comprehensive smart city integration.

In conclusion, real-time bus tracking systems represent a critical component of modern urban transportation infrastructure with demonstrated benefits including reduced waiting times, improved service reliability, and enhanced passenger satisfaction. Continued research and development addressing identified challenges and leveraging emerging technologies will further enhance these systems' capabilities and impact, contributing to more efficient, sustainable, and accessible urban mobility.

REFERENCES

[1] United Nations, Department of Economic and Social Affairs, "World Urbanization Prospects: The 2018 Revision," United Nations, New York, 2019.
[2] R. Kumar and P. Singh, "Challenges in Urban Public Transportation: A Systematic Review," IEEE Transactions on Intelligent Transportation Systems, vol. 21, no. 4, pp. 1523-1536, Apr. 2020.
[3] J. Zhang, M. Chen, and L. Wang, "GPS-Based Real-Time Bus Tracking System Architecture," Journal of Transport and Land Use, vol. 12, no. 3, pp. 445-462, 2019.
[4] S. Patel and R. Kumar, "Passenger Pain Points in Urban Public Transportation: A SurveyBased Study," Transportation Research Part C, vol. 118, pp. 102-118, Sept. 2020.
[5] R. Kumar and P. Singh, "Impact of Real-Time Information Systems on Public Transport Ridership," IEEE Intelligent Transportation Systems Magazine, vol. 12, no. 2, pp. 45-58, Summer 2020.
[6] M. Anderson, K. Thompson, and J. Lee, "Operational Benefits of Real-Time Tracking in Transit Management," Transportation Research Record, no. 2675, pp. 234-248, 2021.

[7] P. Misra and P. Enge, Global Positioning System: Signals, Measurements, and Performance, 2nd ed. Lincoln, MA: Ganga-Jamuna Press, 2006.
[8] L. Chen, H. Yang, and X. Zhou, "GPS Accuracy Analysis in Urban Environments for Transportation Applications," IEEE Sensors Journal, vol. 19, no. 18, pp. 8234-8245, Sept. 2019.
[9] T. Rahman and Y. Chen, "Comparison of Dedicated vs. Smartphone-Based GPS Tracking for Public Transit," Journal of Public Transportation, vol. 23, no. 1, pp. 89-104, 2020.
[10] A. Sharma and K. Patel, "Mobile Application Development Frameworks for Transportation Systems: A Comparative Study," International Journal of Mobile Computing and Multimedia Communications, vol. 14, no. 2, pp. 78-95, 2023.
[11] Google, "Flutter Documentation: Technical Overview," Google LLC, 2024. [Online]. Available: https://flutter.dev/docs
[12] P. Mell and T. Grance, "The NIST Definition of Cloud Computing," National Institute of Standards and Technology, Special Publication 800-145, Sept. 2011.
[13] S. Kumar and R. Verma, "Performance Evaluation of Firebase Realtime Database for Location Tracking Applications," International Journal of Cloud Computing, vol. 11, no. 5, pp. 567-582, 2022.
[14] D. Richardson and M. Wallace, "Three-Tier Architecture for Scalable Web Applications," ACM Computing Surveys, vol. 52, no. 1, pp. 1-28, 2019.
[15] N. Leavitt, "Will NoSQL Databases Live Up to Their Promise?," Computer, vol. 43, no. 2, pp. 12-14, Feb. 2010.
[16] M. Hickman and N. Wilson, "Passenger Travel Time and Path Choice Implications of RealTime Transit Information," Transportation Research Part C, vol. 3, no. 4, pp. 211-226, 1995.
[17] S. Patel and R. Kumar, "Third-Generation Transit Tracking Systems: Integration and Innovation," Journal of Advanced Transportation, vol. 2021, Article ID 9987654, 2021.
[18] V. Singh and M. Gupta, "SmartBus: An Android-Based Public Transport Tracking System," International Journal of Computer Applications, vol. 178, no. 23, pp. 12-18, 2019.
[19] J. Li, Y. Chen, and X. Wang, "CloudBus: A Cross-Platform Real-Time Bus Tracking Application Using Flutter and Firebase," IEEE Access, vol. 9, pp. 88745-88758, 2021.
[20] R. Thompson, S. Anderson, and M. Lee, "AI-Powered Public Transit Systems: A Case Study of SmartCity Transit," Transportation Science, vol. 58, no. 2, pp. 234-251, 2024.
[21] H. Petersen, N. Saunders, and D. Pozdnoukhov, "Bus Arrival Time Prediction Using Machine Learning Techniques," Transportation Research Record, no. 2417, pp. 46-55, 2014.
[22] X. Zhang and H. Wang, "Deep Learning Approaches for Bus Arrival Time Prediction: A Comparative Analysis," IEEE Transactions on Intelligent Transportation Systems, vol. 24, no. 8, pp. 8792-8804, 2023.
[23] K. Anderson, L. Wilson, and J. Martinez, "User Experience Design Principles for Transit Mobile Applications," International Journal of Human-Computer Interaction, vol. 38, no. 12, pp. 1145-1162, 2022.
[24] S. Newman, Building Microservices: Designing Fine-Grained Systems, 2nd ed. Sebastopol, CA: O'Reilly Media, 2021.
[25] European Parliament and Council, "General Data Protection Regulation (GDPR)," Regulation (EU) 2016/679, Apr. 2016.