IJARCCE ISSN (O) 2278-1021, ISSN (P) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering

Impact Factor 8.471 ⁙ Peer-reviewed & Refereed journal ⁙ Vol. 15, Issue 5, May 2026

DOI: 10.17148/IJARCCE.2026.15503

Smart Hybrid Bus Tracking System with Mobile Sensing and Real-Time Updates

Anil Kumar T R[1], Harshavardhan Pattar[2], Indusri J[3], Joshi Chetan[4],

Dr. Yeresime Suresh[5], Dr. Anita Patil[6]

6th Sem B.E.(CS&AI), Ballari Institute of Technology and Management (BITM), Ballari, Karnataka-583104, India[1-4]

Head of The Departement, Department of Computer Science and Artificial Intelligence Engineering.

Ballari Institute of Technology and Management (BITM), Ballari, Karnataka 583104, India[5]

Professor, Department of Computer Science and Artificial Intelligence Engineering.

Ballari Institute of Technology and Management (BITM), Ballari, Karnataka 583104, India[6]

Abstract: Growing urban populations have created an increasing need for intelligent public transportation systems, with real-time bus tracking becoming a critical requirement. Traditional approaches rely extensively on specialized GPS equipment, creating significant costs and operational challenges. This research presents a Smart Hybrid Bus Tracking System that utilizes smartphones that drivers and passengers already carry, removing the requirement for dedicated hardware. The system uses the driver's mobile device as the main location provider, with passenger smartphone data enhancing position precision. During network outages, the platform saves information locally and updates it when connectivity returns. The system also integrates sophisticated algorithms such as Kalman Filter, XGBoost, and LSTM to improve prediction accuracy. This approach delivers a cost-effective, flexible, and practical tracking solution that works effectively across various real-world applications.

Keywords: Bus Tracking, GPS, Mobile Sensing, Real-Time System, Kalman Filter, XGBoost, LSTM, Smart Transportation

I. INTRODUCTION

Bus services across India see widespread use, yet passengers face significant difficulties due to the lack of real-time updates on bus locations and schedules. While buses may follow their planned timetables, factors like traffic congestion, weather, and poor road conditions frequently cause delays.

Given the widespread adoption of smartphones and internet connectivity, traditional methods can be transformed through digital solutions. Current tracking systems typically rely on costly and complicated GPS equipment.

This proposed solution offers bus tracking through mobile devices, providing an affordable alternative since it requires no extra hardware beyond the GPS capabilities already built into smartphones that both drivers and passengers carry.

II. THEORETICAL BACKGROUND

The Smart Hybrid Bus Tracking System we propose combines mobile sensing capabilities, GPS technology, and machine learning methods to deliver precise real-time bus positioning and arrival time forecasts. This section outlines the core concepts and models that form the foundation of our system.

A. System Architecture

We can describe the system as a functional framework that transforms input information into useful results:

• Input (I): GPS coordinates from both drivers and passengers, route details, time records

• Processing (P): Data cleaning, integration, and forecasting algorithms

• Output (O): Current bus position and projected arrival times

The system operates according to this relationship:

$O = f(I, P)$

International Journal of Advanced Research in Computer and Communication Engineering
Impact Factor 8.471 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 15, Issue 5, May 2026
DOI: 10.17148/IJARCCE.2026.15503

Here, function f represents the data processing and prediction mechanisms.

B. GPS Location Detection

Our system depends mainly on GPS (Global Positioning System) capabilities built into smartphones to track bus locations in real time. GPS delivers latitude and longitude coordinates that enable movement monitoring.

GPS precision can be compromised by several factors:

• Signal interference in city environments (urban canyon effect)

• Adverse weather patterns

• Device hardware constraints

To address these challenges, the system incorporates alternative methods:

• Mobile network positioning

• Wi-Fi location services

C. Information Integration Methods

The system enhances precision by merging data from multiple sources (both drivers and passengers) through advanced data fusion approaches.

Kalman Filter

• A computational method that estimates precise positions from unreliable GPS readings

• Operates through two phases: forecasting and adjustment

• Minimizes tracking errors during real-time operations

D. Predictive Learning Algorithms

Our system uses machine learning techniques to forecast bus arrival schedules.

1. XGBoost

• A supervised learning method built on gradient boosting principles

• Processes extensive datasets with high efficiency

• Delivers superior accuracy for travel duration predictions

2. LSTM (Long Short-Term Memory)

• A specialized Recurrent Neural Network (RNN) variant

• Designed for sequential data analysis

• Identifies recurring patterns such as traffic fluctuations and service delays

E. Route Alignment Processing

GPS readings don't always correspond precisely to actual roadways. Route alignment methods correct GPS coordinates to match the proper bus pathway.

Hidden Markov Model (HMM)

• Evaluates potential routes and identifies the most likely path

• Substantially enhances location precision

F. Connectivity-Independent Data Management

When internet access is limited, the system employs offline storage solutions:

International Journal of Advanced Research in Computer and Communication Engineering
Impact Factor 8.471 ⁝⁝ Peer-reviewed & Refereed journal ⁝⁝ Vol. 15, Issue 5, May 2026
DOI: 10.17148/IJARCCE.2026.15503

• Information gets temporarily saved in device memory

• Data uploads automatically once connectivity returns

This approach maintains uninterrupted tracking without information loss.

G. Arrival Prediction Framework

The system calculates estimated arrival time (ETA) using several factors:

• Present bus position

• Remaining distance to the next station

• Current travel speed

• Traffic flow conditions

The basic calculation follows:

ETA = Distance / Speed

More sophisticated models enhance this formula through machine learning forecasts.

H. System Evaluation Standards

We measure system effectiveness using these criteria:

• Accuracy: Variance between forecasted and actual arrival times

• Latency: Response time for location updates

• Reliability: Performance consistency during network disruptions

III. FOUR-TIER TAXONOMY

To gain a clearer perspective on how bus tracking systems have developed and what they can accomplish, we can organize them according to their technological sophistication, features, and how well they integrate with other systems. Our proposed system fits into a four-level classification structure outlined here:

Level 1: Manual Bus Information Systems

This represents the most fundamental approach to bus tracking.

• Passengers depend on printed timetables or asking for information in person

• Real-time tracking does not exist

• Information frequently becomes unreliable because of traffic jams or bad weather

• No computerized or automatic systems provide support

Limitations:

• Passengers face significant uncertainty

• Waiting periods become longer

• Bus locations remain completely unknown

Level 2: GPS-Based Hardware Tracking Systems

This level involves installing specialized GPS tracking equipment on buses.

• Buses transmit their exact locations through built-in GPS devices

• Information flows to a central control system

ISSN (O) 2278-1021, ISSN (P) 2319-5940
International Journal of Advanced Research in Computer and Communication Engineering
Impact Factor 8.471 ⁙ Peer-reviewed & Refereed journal ⁙ Vol. 15, Issue 5, May 2026
DOI: 10.17148/IJARCCE.2026.15503

• Passengers can view basic tracking information through apps or electronic displays

Advantages:

• Location tracking becomes more precise

• Updates happen in real time

Limitations:

• Equipment setup and upkeep costs remain expensive

• Additional hardware infrastructure becomes necessary

• Expanding to cover entire bus fleets proves difficult

Level 3: Mobile-Based Bus Tracking Systems

This approach uses smartphones instead of specialized tracking equipment.

• Bus drivers use their personal phones to provide GPS location data

• Information gets shared through mobile apps

• Eliminates the need for costly dedicated hardware

Advantages:

• Offers an affordable approach

• Simple to implement and manage

• Takes advantage of current mobile technology

Limitations:

• Relies exclusively on information from drivers

• GPS accuracy can drop in areas with poor signal reception

• No backup data sources exist

Level 4: Smart Hybrid Bus Tracking System (Proposed System)

This represents the most sophisticated level and describes our proposed approach.

• Gathers location data from both drivers and passengers using mobile devices

• Applies data fusion methods to enhance precision

• Incorporates advanced algorithms including Kalman Filter, XGBoost, and LSTM

• Includes offline data storage and live synchronization features

• Delivers precise arrival time estimates and continuous location updates

Advantages:

• Achieves superior accuracy and dependability

• Remains affordable and easy to expand

• Functions effectively even with poor internet connections

• Creates a better experience for users

IJARCCE ISSN (O) 2278-1021, ISSN (P) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering

Impact Factor 8.471 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 15, Issue 5, May 2026

DOI: 10.17148/IJARCCE.2026.15503

Taxonomy Summary

Our proposed Smart Hybrid Bus Tracking System belongs to Level 4 because it brings together cutting-edge technologies like mobile sensing, data fusion, and machine learning. It addresses the shortcomings of previous systems by delivering a tracking solution that can grow with demand while maintaining accuracy and efficiency in real-time operations.

IV. LITERATURE REVIEW

Research on predicting bus arrivals and travel times has made considerable progress through intelligent transportation systems and models based on data analysis. Initial methods depended primarily on statistical approaches like Kalman Filter and ARIMA, which offered reasonable prediction performance but had difficulty handling changing traffic patterns. Current research emphasizes machine learning and deep learning techniques such as XGBoost, SVM, and LSTM that successfully identify spatial and temporal relationships in live data streams. These approaches incorporate various data sources including GPS information, weather patterns, and passenger volume to enhance prediction reliability. Comparison studies reveal that ensemble techniques like XGBoost deliver superior accuracy and efficiency compared to conventional approaches. The adoption of artificial intelligence methods has significantly improved the dependability and effectiveness of contemporary bus monitoring systems.

TABLE I: LITERATURE REVIEW SUMMARY

Sl.	Author(s)	Year & Title	Method/ Technique	Key Findings	Venue & Index
1	Zhang X. et al.	2022 – Travel Time Prediction of Urban Public Transportation	Kalman Filter, GPS Data	Improved short-term travel time prediction accuracy using multi-source data	PLOS ONE (SCI Indexed)
2	Vidya G S et al.	2020 – Passenger Flow Estimation in Bus Route	Kalman Filter, Geometric Brownian Motion	Efficient passenger flow estimation for better scheduling and reduced waiting time	IEEE Conference
3	Zhu L. et al.	2022 – XGBoost-Based Travel Time Prediction	XGBoost, Machine Learning	Achieved high prediction accuracy compared to KNN and Neural Networks	Wireless Communications & Mobile Computing (SCI)
4	Abdi A. & Amrit C.	2021 – Review of Travel & Arrival Prediction Methods	Survey (ML, Statistical, Hybrid	Provided taxonomy and identified challenges in prediction models	PeerJ Computer Science (Scopus Indexed)
5	Pov P. et al.	2025 – Bus Arrival Time Prediction Using ML	XGBoost, SVM, KNN, ANN	XGBoost showed best performance with lowest error rates	Techno-Science Research Journal
6	Chen C.H. et al.	2019 – Bus Arrival Time Prediction using RNN	Recurrent Neural Networks	Captured temporal dependencies for improved arrival prediction	IEEE Transactions

International Journal of Advanced Research in Computer and Communication Engineering
Impact Factor 8.471 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 15, Issue 5, May 2026
DOI: 10.17148/IJARCCE.2026.15503

7	Pang G. et al.	2018 – Deep Learning for Bus Arrival Prediction	LSTM, Deep Learning	Improved long-term dependency handling in traffic prediction	IEEE Access
8	Yang Y. et al.	2017 – Bus Arrival Prediction using SVM	SVM, Genetic Algorithm	Enhanced prediction accuracy with optimized parameters	IEEE Conference

V. COMPARATIVE ANALYSIS

Current bus tracking systems differ significantly in their technology, precision, expense, and ability to expand. By comparing these various approaches, we can better understand what works well and what doesn't, while also showing how our proposed system offers improvements.

Most traditional systems depend on manual processes or GPS hardware for tracking. Newer methods have started using mobile sensors and machine learning algorithms, though many of these solutions struggle with poor integration and low efficiency. Our proposed system addresses these shortcomings by bringing together several technologies within a single, cohesive framework.

TABLE II: COMPARATIVE ANALYSIS OF REVIEWED SYSTEMS

Sl. No	System / Approach	Technique Used	Performance	Advantages	Limitations
1	Manual System	Fixed schedules	Low	Simple implementation	No real-time tracking
2	GPS Hardware-Based System	Dedicated GPS devices	Moderate	Accurate location tracking	High cost, maintenance required
3	Basic Mobile Tracking	Driver mobile GPS	Moderate	Cost-effective, easy to deploy	Depends only on driver data
4	ML-Based Prediction System	ML algorithms (KNN, SVM)	High	Better prediction accuracy	Requires large datasets
5	IoT-Based Tracking	Sensors + GPS + Cloud	High	Real-time monitoring	Expensive infrastructure
6	Map Matching System	HMM algorithms	High	Improves route accuracy	Complex implementation
7	Proposed Hybrid System	Mobile sensing + ML (KF, XGBoost, LSTM)	Very High	Accurate, scalable, cost-effective	Depends on user participation

VI. RESEARCH GAP

While bus tracking and prediction systems have made notable progress, current approaches still face several important limitations. These shortcomings demonstrate the necessity for a more effective, comprehensive, and expandable solution.

Gap 1 - Absence of Unified Systems

Current solutions typically concentrate on separate elements like tracking, prediction, or user interfaces. No comprehensive system exists that combines real-time tracking, prediction capabilities, and user interaction within one cohesive platform.

Gap 2 - Reliance on Costly Hardware

Numerous systems require specialized GPS equipment to be installed in buses. This approach leads to:

• Higher installation expenses

International Journal of Advanced Research in Computer and Communication Engineering
Impact Factor 8.471 ⁙ Peer-reviewed & Refereed journal ⁙ Vol. 15, Issue 5, May 2026
DOI: 10.17148/IJARCCE.2026.15503

• Increased maintenance challenges

• Greater deployment obstacles

These systems prove impractical for widespread implementation, particularly in developing areas.

Gap 3 - Restricted Data Input Sources

Current mobile-based tracking solutions rely exclusively on the driver's device. This limitation results in:

• A single point of system failure

• Decreased precision when GPS signals weaken

• Absence of backup data collection methods

Gap 4 - Unreliable Arrival Time Estimates

Multiple systems employ simple calculation methods that fail to account for:

• Current traffic situations

• Time-based patterns

• Past performance data

These oversights lead to unreliable prediction results.

Gap 5 - Inadequate Function in Areas with Poor Connectivity

Most systems need constant internet access. In practical situations:

• Network interruptions frequently occur

• Information may be lost

• Tracking reliability suffers

Gap 6 - Missing Data Integration Methods

Many current systems fail to employ multi-source data integration, which could substantially enhance location precision and system dependability.

Gap 7 - Problems with System Expansion

Certain solutions work for limited deployments but encounter difficulties when:

• User numbers expand

• Data quantities increase

• System demands intensify

Gap 8 - Insufficient Application of Advanced Machine Learning

While machine learning technologies are available, many systems:

• Fail to incorporate them properly

• Rely on simple algorithms only

• Cannot process real-time changing data effectively

International Journal of Advanced Research in Computer and Communication Engineering

Impact Factor 8.471 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 15, Issue 5, May 2026

DOI: 10.17148/IJARCCE.2026.15503

CONCLUSION

This research introduces an affordable and expandable bus tracking solution that operates through mobile devices. The approach cuts down on implementation expenses by removing the requirement for specialized hardware while preserving system dependability.

Combining offline data storage capabilities with machine learning methods boosts functionality even when network connectivity is poor. The solution enhances the passenger journey by delivering live information and minimizing wait times.

Planned enhancements for the future include:

• Improved machine learning algorithms for more accurate forecasting

• Connection with smart city systems

• Support for multiple languages

REFERENCES

[1] Zhang, X., Lauber, L., Liu, H., Shi, J., Xie, M. and Pan, Y., 2022. Travel time prediction of urban public transportation based on detection of single routes. Plos one, 17(1), p.e0262535.

[2] Vidya, G.S., Hari, V.S. and Shivasagaran, S., 2020, March. Estimation of passenger flow in a bus route using Kalman filter. In 2020 6th International Conference on Advanced Computing and Communication Systems (ICACCS) (pp. 1248-1251). IEEE.

[3] Zhu, Lingxiang, Sisi Shu, and Liang Zou. "XGBoost-Based Travel Time Prediction Between Bus Stations and Analysis of Influencing Factors." Wireless Communications and Mobile Computing 2022.1 (2022): 3504704.

[4] Abdi, Asad, and Chintan Amrit. "A review of travel and arrival-time prediction methods on road networks: classification, challenges and opportunities." PeerJ Computer Science 7 (2021): e689.

[5] Lam, Ka Nam. "Traffic Prediction Using LSTM, RF and XGBoost." (2025).

[6] Sridevi, K., et al. "Smart bus tracking and management system using IoT." Asian Journal of Applied Science and Technology (AJAST) Volume 1 (2017).

[7] Sun, Mingkang, and Xiang Li. "Traffic trajectory data analysis technology based on HMM model map matching algorithm." Plos one 19.5 (2024): e0302656.

[8] Varma, Nadimpalli Madana Kailash, et al. "Machine learning-enabled smart transit: real-time bus tracking system for enhanced urban mobility." 2024 Intelligent Systems and Machine Learning Conference (ISML). IEEE, 2024.

[9] SP, Jayaraam, et al. "Bus Tracking System using Mobile GPS Technology." 2024 International Conference on Inventive Computation Technologies (ICICT). IEEE, 2024.

[10]Achar, Avinash, et al. "Bus arrival time prediction: A spatial Kalman filter approach." IEEE Transactions on Intelligent Transportation Systems 21.3 (2019): 1298-1307.

[11]Wei, Shouchen, et al. "Bus Load Prediction Based on Subtraction Clustering and XGboost." 2023 IEEE/IAS Industrial and Commercial Power System Asia (I&CPS Asia). IEEE, 2023.

[12] Arora, Mohit, et al. "Multi-Sensor Fusion and Machine Learning for Real-Time Collision Warning in Autonomous Driving." 2025 IEEE 4th International Conference for Advancement in Technology (ICONAT). IEEE, 2025.

[13]Liu, Hongjie, et al. "Bus arrival time prediction based on LSTM and spatial-temporal feature vector." IEEE Access 8 (2020): 11917-11929.

[14] Mansurova, Aigerim, Aiganym Mansurova, and Aivar Sakhipov. "Bus Arrival Time Prediction via Hybrid LSTM Using GPS-Derived Run and Dwell Times." VEHITS. 2025.