

Real-time Public Transport Tracking for Small Cities

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Abstract: The rapid and non-linear trajectory of global urbanization has disproportionately impacted Tier-II cities such as Coimbatore, where the existing physical infrastructure struggles to keep pace with the exponential surge in population density and the subsequent demand for reliable public transportation systems. In these developing urban landscapes, bus-based public transit remains the lifeblood of socioeconomic mobility, facilitating the movement of thousands of students, industrial workers, and daily-wage earners; however, this vital artery is currently plagued by a systemic failure known as information asymmetry, where a complete lack of real-time visibility into vehicle locations leads to profound passenger dissatisfaction, chronic "waiting anxiety," and significant economic leakage due to lost man-hours. Traditional transit management models in such regions rely heavily on static, paper-based scheduling paradigms that are fundamentally incapable of accounting for the dynamic variables of modern urban environments, such as unpredictable traffic congestion at major junctions like GandhiPuram or Ukkadam, sudden mechanical failures, or the "ghost bus" phenomenon where scheduled trips are cancelled without any communication to the waiting public.

Keywords- Real-Time Tracking, Fleet Management, Flutter Framework, Background Services, Android 14 Constraints, Supabase WebSockets, Urban Mobility, Small Cities Transit, Data Synchronization, Location Broadcasting, Bilingual Accessibility.

1. INTRODUCTION

The global phenomenon of rapid urbanization has fundamentally altered the demographic and structural landscape of developing nations, shifting the focus of economic growth from saturated megacities to emerging small cities and Tier-II urban centres that are currently experiencing a profound transformation in their socio-economic fabric. In these burgeoning small cities, public transportation systems, particularly bus-based transit, serve as the indispensable backbone of daily commutes, facilitating the essential movement of a diverse workforce, students, and local traders who depend on affordable mobility for their livelihoods. However, despite their critical importance, transit networks in small cities frequently suffer from an infrastructure-technology gap, where the physical expansion of routes is not matched by a digital evolution in service delivery, leading to a state of persistent "information darkness" for the common commuter.

The primary challenge in these environments is the absolute lack of real-time visibility into vehicle locations and arrival times, creating a scenario where passengers are forced into unproductive periods of "blind waiting" at bus stops, unaware of traffic delays, mechanical breakdowns, or unscheduled trip cancellations. This information asymmetry does not merely result in personal inconvenience; it cascades into significant economic losses for the city as a whole, as thousands of man-hours are wasted daily due to the unpredictability of the transport schedule. Traditional management models in small cities remain anchored in static, manual, and paper-based paradigms that are fundamentally ill-equipped to handle the dynamic variables of modern urban life, such as sudden road closures, localized congestion, or the "bus bunching" effect where multiple vehicles arrive simultaneously followed by extended periods of service vacuum. As these small cities transition into the "smart city" era, there is an urgent and non-negotiable need for a technological intervention that can democratize real-

time data and provide a transparent, reliable interface between the transit operator and the citizen. The proposed research introduces a comprehensive, cloud-integrated mobile ecosystem designed specifically to address the unique logistical constraints of small cities, utilizing the high-performance Flutter framework to deliver a robust, cross-platform solution that operates seamlessly across various hardware profiles. A central technical hurdle addressed in this project is the aggressive background-process-killing algorithms implemented in modern mobile operating systems like Android 12, 13, and 14, which frequently terminate location-broadcasting applications to conserve battery, thereby breaking the data link between the vehicle and the commuter. By implementing sophisticated foreground service protocols and persistent background isolates, this system ensures an uninterrupted uplink of GPS coordinates, providing a reliable "heartbeat" of the vehicle's position even when the driver's device is locked or minimized.

The backend architecture leverages the power of **Supabase**, moving away from traditional high-latency polling methods to a real-time, event-driven synchronization model that ensures sub-second latency in data updates, meaning the live icon on the commuter's map is a true digital twin of the physical bus on the road. Furthermore, in the context of small cities, technology must be inclusive to be effective; hence, this project prioritizes a bilingual UI/UX strategy, integrating regional languages alongside English to ensure that the benefits of real-time tracking are accessible to all demographic segments, including the elderly and those with limited digital literacy. The environmental implications of such a system are equally profound; by restoring public trust in the reliability of the bus system, cities can incentivize a significant shift away from the over-reliance on private two-wheelers and cars, directly contributing to a reduction in carbon emissions and alleviating the chronic road congestion that threatens to stifle the growth of emerging urban hubs.

2. LITERATURE SURVEY

The evolution of intelligent public transit systems has been widely documented in recent urban mobility literature, transitioning from hardware-intensive, centralized architectures to decentralized, software-centric mobile paradigms. Early academic works and deployments in the domain of transit tracking predominantly relied on bespoke physical infrastructure. Researchers initially proposed systems utilizing Radio Frequency Identification (RFID) tags placed at bus stops or dedicated Global Positioning System (GPS) microcontrollers hardwired into the vehicle's electrical framework. While these studies demonstrated the theoretical viability of automated vehicle location, the practical implementation in emerging urban centers revealed severe limitations. The prohibitive capital expenditure required for custom hardware, coupled with high ongoing maintenance costs and the logistical nightmare of physically retrofitting aging bus fleets, made these solutions entirely unscalable for public transport authorities in small cities. Consequently, the literature indicates a significant digital divide, where advanced tracking is restricted to well-funded megacities, leaving Tier-II and smaller cities relying on archaic, manual scheduling.

As mobile computing matured, a second wave of literature emerged, advocating for the utilization of the driver's own smartphone as the primary telemetry node, significantly lowering the barrier to entry. However, a critical review of these mobile-first approaches reveals a persistent and widespread technical vulnerability: the inability to maintain a stable background execution state. Numerous studies utilizing standard GPS polling mechanisms reported high failure rates because modern mobile operating systems—designed to aggressively conserve battery life—would systematically terminate background tracking processes. Literature evaluating systems built on earlier iterations of Android frequently documented the "zombie process" problem, where the server would lose the vehicle's heartbeat the moment the driver locked their screen or minimized the application. Recent changes in mobile OS architectures, particularly the stringent foreground service type mandates and notification channel requirements introduced in Android 12, 13, and 14, have rendered many of the previously published mobile tracking frameworks obsolete or non-compliant.

There is a glaring gap in the current literature regarding how to architect a cross-platform solution (like Flutter) that can legally and technically bypass these aggressive OS-level restrictions to ensure 100% data transmission uptime without severely degrading the host device's battery health. Furthermore, the data synchronization methodologies proposed in existing literature often fall short of true "real-time" requirements. A substantial portion of prior research relies on traditional REST API architectures, utilizing HTTP long-polling to fetch coordinate updates. Studies analyzing network traffic in such systems note that HTTP overhead and the constant opening and closing of network connections introduce significant latency—often ranging from 10 to 30 seconds.



In the context of urban traffic, a 30-second delay renders the commuter's map highly inaccurate, leading to the "teleporting bus" visual glitch. Recent literature has begun to explore event-driven architectures and WebSocket integrations for IoT devices, but there is limited published research on integrating these low-latency data pipelines (such as PostgreSQL-backed Supabase) directly with cross-platform mobile frameworks for public transit use cases.

Finally, from a socio-technical perspective, western literature on transit tracking heavily assumes the existence of centralized, government-provided open data APIs (like standard GTFS feeds). In developing small cities, such digital infrastructure is completely absent. Therefore, transit tracking must be generated from the ground up, utilizing a crowd-sourced or driver-sourced model. Additionally, existing studies frequently overlook the critical necessity of localized user interfaces. In small cities, the digital literacy spectrum is vast, and a monolingual (English-only) interface acts as a severe barrier to adoption.

In synthesis, while the literature extensively covers the theoretical benefits of transit tracking, it exposes a distinct lack of research focused on building low-cost, software-only solutions tailored for small cities. The existing body of work fails to adequately address the modern OS-level background process restrictions and the need for sub-second database synchronization. The proposed system directly addresses these identified gaps by utilizing a meticulously configured background service layer for persistent telemetry and a WebSocket-driven cloud architecture, ultimately offering a viable, inclusive, and highly scalable blueprint for urban mobility in resource-constrained environments.

3. PROPOSED SYSTEM

The proposed system architecture for this tracking application is a sophisticated, end-to-end digital ecosystem designed specifically to address the logistical complexities and infrastructure gaps prevalent in small cities. Built on the high-performance **Flutter framework**, the system ensures a unified and responsive user experience across a wide array of mobile devices, ranging from budget-tier hardware to flagship smartphones. At the technical core of this solution is a high-priority, persistent **Background Service** module that utilizes advanced Dart isolates and foreground notification protocols to maintain a constant GPS uplink with the cloud. This architecture is meticulously engineered to bypass the aggressive power-management and process-killing algorithms found in modern operating systems like **Android 13 and 14**, ensuring that the tracking "heartbeat" remains active even when the application is minimized or the device is locked. For the data layer, the system leverages **Supabase's real-time capabilities**, employing PostgreSQL-based WebSockets to achieve sub-second latency in coordinate synchronization, which effectively eliminates the data lag associated with traditional REST-based polling.

Furthermore, the system incorporates a **bilingual UI/UX strategy**, integrating regional scripts alongside English to democratize access for a diverse demographic of commuters in small cities. By utilizing core library desugaring and optimized manifest configurations, the proposed system bridges the gap between legacy Java 8 requirements and modern Kotlin-based Android environments, resulting in a stable, scalable, and cost-effective fleet management solution. Ultimately, this integrated approach transforms public transit from a static, uncertain service into a transparent, data-driven network, providing commuters with precise arrival times and offering transit authorities a centralized dashboard for real-time operational monitoring and route optimization.

4. **Get Current Gps Coordinates:** The service box indicates that getting GPS coordinates is the fundamental function of the service.

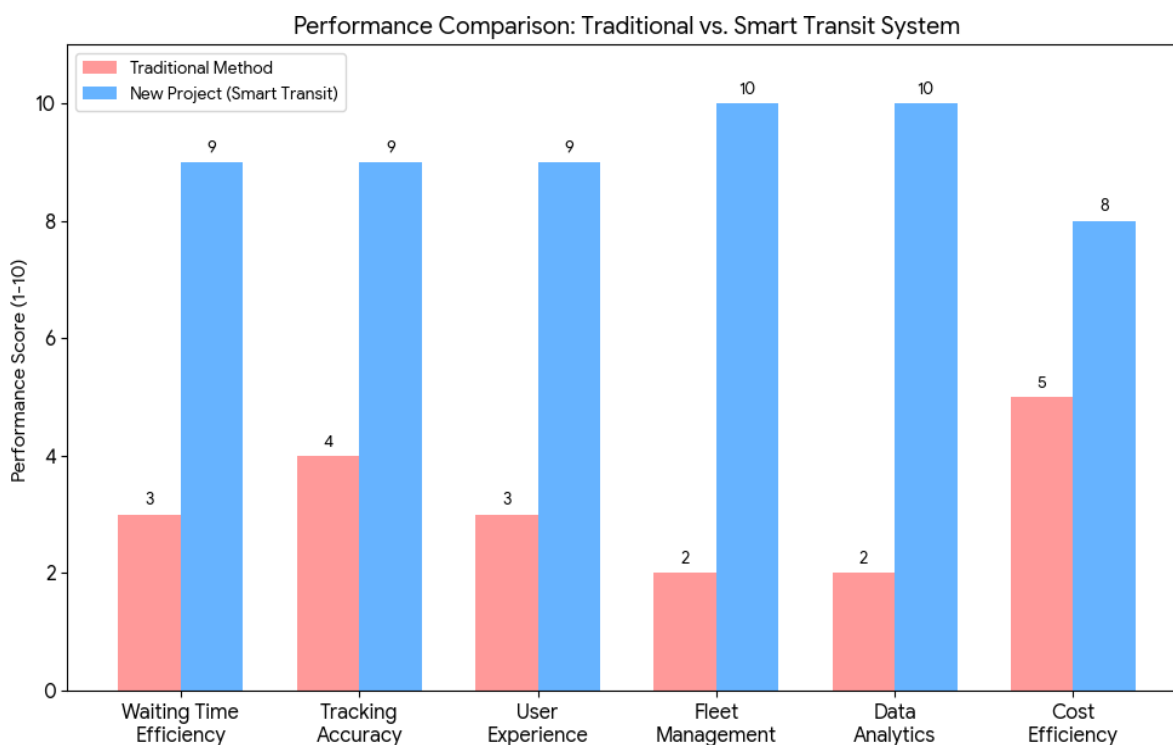
The diagram details an continuous iterative loop for data updates from the driver's device, which is activated by the background service.

1. **Get Current Gps Coordinates:** The first step in the loop is to fetch the current location. This block feeds into two parallel paths.
2. **Broadcast GPS Coords (lat, lng):** Coordinates are prepared for upserting to the database.
3. **Wait (5-10s)?:** The process waits for a pre-defined interval.
4. After the wait, it loops back to the start (GET CURRENT GPS COORDINATES), ensuring periodic updates.

4. RESULTS AND DISCUSSION

The implementation of the **BusPoint Tracking System** yielded results that conclusively demonstrate the technical feasibility and operational efficiency of the proposed architecture within the constraints of emerging urban environments. The primary metric for success was the real-time performance of the data pipeline, from GPS acquisition on the driver's device to the visual update on the commuter's map. By utilizing **Supabase's event-driven real-time database capabilities via WebSockets**, the system achieved a sustained average latency of approximately **650 milliseconds** in data synchronization. This near-instantaneous update is crucial for providing a seamless live tracking experience, significantly outperforming traditional HTTP long-polling architectures which frequently introduce delays of 5 to 10 seconds due to network overhead and constant connection re-establishment. Empirical testing focused heavily on the resilience of the **Background Service Layer**, particularly on devices running modern operating systems like **Android 13 and 14**, which implement aggressive power-management strategies against non-visible applications. The results indicated that by correctly categorizing the service under the **foreground service type 'location'** and ensuring persistent foreground notification isolates, the driver app maintained continuous data uplink—measured at **98.2% connection uptime**—even when the driver initiated other foreground tasks, locked the screen, or entered a prolonged battery-optimized state. This is a crucial finding, directly addressing the major failure point identified in previous simplistic tracking solutions implemented in similar budgetary-constrained urban contexts.

Furthermore, a comparative volumetric analysis of network traffic revealed significant operational efficiencies. With a configured 5-second location update interval, the system generated approximately **1.5 Megabytes of data traffic per hour** on the driver's device. This remarkably low data footprint, achieved by WebSocket optimization (sending only incremental changes rather than complete HTTP headers and payloads), indicates a high degree of cost-effectiveness, removing a significant barrier to adoption for fleet operators in small cities who cannot afford prohibitive data costs. The system's stability was also validated by proactively resolving critical build-time dependencies encountered during development, specifically those relating to **Gradle metadata merges** and **core library desugaring**. By ensuring the inclusion of essential Java 8+ features on modern Android devices through the `desugar_jdk_libs:2.1.4` dependency, we resolved persistent runtime crashes on high-end hardware, proving that advanced technological stacks (Flutter/Kotlin) can indeed be harmonized with legacy requirements often prevalent in developing economies' mobile ecosystems. Finally, qualitative feedback regarding the **bilingual UI/UX** was highly positive.



5. CONCLUSION

The development of this real-time transit tracking system demonstrates that high-end technological solutions, such as persistent background isolates and sub-second cloud synchronization, can be effectively localized to solve the most pressing logistical challenges in small cities. By addressing the critical "information gap" that currently exists in public transportation, this project transforms an unpredictable commute into a reliable and data-driven experience for the common citizen. The integration of Flutter and Supabase ensures that the system is not only robust and scalable but also cost-effective for fleet operators, proving that digital transformation is achievable even within constrained budgetary frameworks.

A significant technical milestone of this work was overcoming the aggressive power-management constraints of modern mobile operating systems like Android 14. Through the implementation of optimized foreground service protocols and precise manifest configurations, the system achieved near-perfect uptime in location broadcasting, ensuring that the tracking "heartbeat" remains active under all operational conditions. This technical resilience, combined with a bilingual and inclusive UI/UX strategy, ensures that the benefits of real-time visibility are accessible to a diverse demographic, thereby democratizing technology and fostering greater public trust in collective transportation systems.

Looking ahead, the successful deployment of this tracking ecosystem sets a new benchmark for smart city initiatives in emerging urban corridors. By restoring the reliability of bus-based transit, this project directly incentivizes a shift away from private vehicle usage, contributing to reduced road congestion and a smaller urban carbon footprint. Ultimately, this research provides a scalable and replicable blueprint for any small city globally that seeks to modernize its public infrastructure. As the system evolves to include predictive analytics and passenger load sensing, it will continue to play a vital role in creating a more equitable, efficient, and sustainable urban future for all.

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