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Ambulance Tracking System (ATS) Using GPS Technology

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Abstract: Rapid urbanization and growing traffic congestion have made it increasingly difficult for ambulances to reach patients on time. In many cases, poor coordination between emergency responders, hospitals, and traffic authorities further delays medical assistance. Such delays can be life-threatening, particularly during the critical "Golden Hour," when timely treatment greatly increases a patient's chances of survival.

This research presents the design and implementation of a Real-Time Ambulance Tracking System (ATS) aimed at reducing these delays through continuous and reliable location monitoring. The system uses GPS technology and persistent WebSocket communication to provide instant location updates. A dual-database architecture combining MongoDB and Redis ensures both secure long-term data storage and high-speed in-memory processing for real-time operations.

A cross-platform mobile application developed using Flutter allows ambulance drivers and traffic police to access live updates and alerts. The backend, built with Node.js and Socket.IO, enables seamless bidirectional communication between users and the server. Experimental testing shows improvements in communication speed, operational visibility, and coordination efficiency.

Overall, the proposed system offers a scalable, cost-effective solution that can support smarter emergency response systems and contribute to the development of modern smart- city infrastructure.

Keywords: Ambulance Tracking System, Real-Time Systems, GPS, Redis, Socket.IO, Flutter, Emergency Response.

I. INTRODUCTION

Emergency Medical Services (EMS) play a vital role in any healthcare system, providing immediate support during accidents, medical emergencies, and natural disasters. Among all EMS components, ambulance services are the most time-critical. Even a delay of a few minutes can significantly influence a patient's survival and recovery. This reality is reflected in the concept of the "Golden Hour," which highlights that medical treatment is most effective when provided within the first sixty minutes after a serious injury or health crisis. Reducing the time between the incident location and hospital care can directly contribute to saving lives.

Despite their importance, ambulance systems in many developing and highly populated urban regions still depend on conventional communication methods such as phone calls, radio communication, and manual record-keeping. While these approaches are operational, they lack the efficiency and transparency required in today's fast-moving environment. Dispatch centers often do not have real-time information about ambulance locations, hospitals may remain uncertain about exact arrival times, and families experience anxiety due to limited updates. This lack of synchronization creates a serious coordination gap among emergency responders, traffic authorities, and hospital staff.

With advancements in mobile technology, GPS tracking, and cloud-based computing, more efficient solutions have become possible. Instead of updating an ambulance's location at fixed intervals, modern systems can continuously transmit live data. Technologies such as WebSockets enable instant communication, NoSQL databases allow flexible data management, and in-memory processing systems provide extremely fast data handling. Together, these tools transform vehicle tracking into a real- time streaming system that accurately reflects movement with minimal delay, offering better situational awareness for all stakeholders.

The primary objective of this project is to utilize these modern technologies to develop a reliable and real-time Ambulance Tracking System (ATS). By replacing costly dedicated hardware with a scalable smartphone-based solution, the system aims to remain affordable and practical, especially in resource-limited settings. The proposed system focuses on continuous live updates, improved coordination between ambulances and hospitals, and minimizing uncertainty during emergency transport.

The following sections present an overview of existing tracking approaches, describe the proposed system architecture, and examine the practical implications and future opportunities of implementing such a digital emergency response solution.

II. LITERATURE REVIEW

Research on emergency vehicle tracking systems generally classifies their development into three evolutionary stages based on communication technology and system capability.

The first generation of tracking systems relied on GSM and SMS-based communication. In these systems, GPS coordinates were transmitted as text messages at regular intervals. Although this approach provided basic tracking functionality, it suffered from significant communication delays and higher operational costs, making it less suitable for time-critical medical emergencies.

The second generation introduced web-based monitoring platforms that used HTTP polling techniques. In this model, client applications repeatedly requested updated location data from the server at fixed time intervals. While this method improved dispatcher visibility compared to SMS-based systems, it placed considerable load on servers and networks due to frequent data requests. Additionally, updates were not truly real- time, as they depended on periodic polling cycles.

The third generation represents modern tracking solutions built on persistent communication protocols such as WebSockets or MQTT. These systems maintain continuous connections between client and server, enabling instant transmission of location data without repeated request cycles. This architecture significantly reduces latency and improves responsiveness.

Several studies emphasize the importance of accurate and continuous tracking in improving emergency response outcomes. Kumar and Singh [3] reported that GSM-based systems often introduce communication delays that may negatively impact medical response during critical situations. Kumar et al. [4] highlighted that although web-based systems enhanced operational monitoring, periodic polling limited their effectiveness in highly dynamic emergency environments. Zhou et al. [5] demonstrated that cloud-supported, real-time communication frameworks allow hospitals and responders to better prepare for incoming cases by receiving immediate updates.

Research by Pande et al. [2] explored IoT-enabled smart ambulance systems, focusing primarily on automation and sensor integration. However, these systems provided limited mechanisms for traffic authority coordination, which remains crucial in densely populated urban areas. Patel and Shah [6] further emphasized the importance of mobile application–based monitoring systems in enhancing situational awareness among emergency teams.

Overall, existing literature reflects a clear transition from delay-prone communication models to continuous, real-time tracking architectures. The trend increasingly focuses on human-centered system design, aiming to reduce uncertainty, improve coordination, and enhance the speed and reliability of emergency medical services.

III. SYSTEM ARCHITECTURE AND DESIGN

The Ambulance Tracking System follows a client- server architecture with real-time communication support. The system is divided into two major components: a backend server and mobile frontend application.

A. Backend Architecture

To handle the high stakes of emergency response, the backend was built using Node.js, TypeScript, and Express.js. This combination provides the speed and reliability needed for systems where every second counts.

Real-Time Communication: We use Socket.IO to create a live heartbeat between the ambulance and the server. This ensures that location updates happen instantly without the lag of traditional requests.

High-Speed Memory: Redis acts as our "short-term memory." It stores live ambulance coordinates in- memory, allowing the system to calculate distances and trigger alerts in milliseconds.

Secure Data Storage: MongoDB serves as our long- term vault, securely storing user profiles and historical trip data, while JSON Web Tokens (JWT) ensure that only authorized personnel can access sensitive information.

B. Frontend Architecture

We chose Flutter to build the mobile application, ensuring that whether a user is on Android or iOS, the experience is seamless and responsive. The app integrates directly with the device's GPS and uses OpenStreetMap to provide clear, real-time navigation.

The app adapts based on who is using it:

- For Ambulance Drivers: A simplified interface focused on "one-tap" location sharing and clear route guidance.

- For Police Authorities: A monitoring dashboard that remains quiet until an ambulance enters their radius, at which point it triggers an immediate visual alert.

C. *Communication Workflow*

Think of the communication workflow as a continuous conversation between the road and the server:
Activation: The driver logs in and begins their shift; the app immediately establishes a secure "handshake" with the server.
Transmission: As the ambulance moves, its GPS coordinates are streamed to the backend via Socket.IO.
Processing: The backend instantly logs this position in Redis and runs a quick "proximity check" against nearby police units.
Action: If the system detects that an ambulance is nearing a police checkpoint, it pushes an instant notification to the officer's device, allowing them to clear traffic before the siren is even heard.

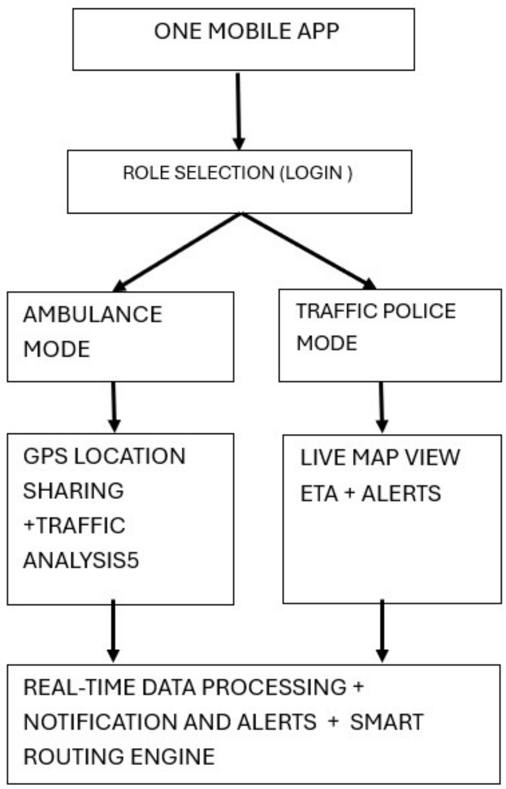

Fig.1 ATS Working Diagram

IV. IMPLEMENTATION & TECHNOLOGIES

The system uses modern, open-source technologies to ensure scalability and maintainability.

- Node.js & TypeScript: Provide a robust and type-safe backend environment.
- Socket.IO: Enables real-time, bidirectional communication.
- Redis: Offers low-latency in-memory data processing for live tracking.
- MongoDB: Stores persistent data efficiently.
- Flutter: Allows rapid development of cross- platform mobile applications.
- OpenStreetMap: Provides free and customizable map services.

These technologies collectively ensure high performance, low latency, and ease of deployment.

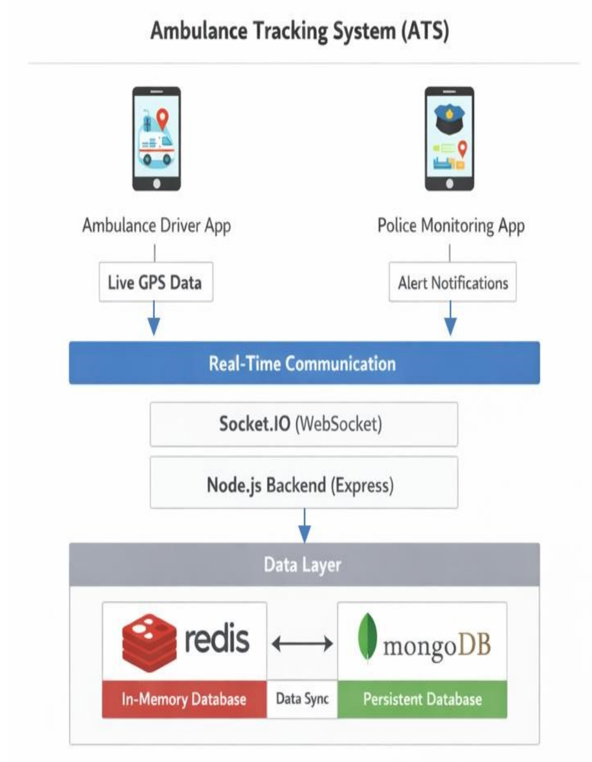

Fig.2 Real-Time Communication Architecture of ATS

V. RESULT

The implemented Ambulance Tracking System showed noticeable improvements in real-time emergency coordination. Continuous GPS tracking with Socket.IO enabled live location updates without delay, reducing communication gaps. Automated proximity alerts successfully provided traffic police with early warnings, allowing them to clear routes in advance.

The integration of Redis ensured fast data processing even during peak conditions. Overall, the system improved response efficiency, reduced uncertainty, and demonstrated strong potential to save critical time during emergency transit.

Sr. No.	Performance Parameter	Test Area (Amravati)	Observed Result	Accuracy (%)
1	GPS Positional Accuracy	Rajkamal Square, Camp Road, VMV Road	Avg deviation 5–9 meters	92%
2	Real-Time Location Transmission	4G network (Jio/Airtel), 50 updates	48 successful transmissions	96%
3	Proximity Alert Detection	500m radius near city checkpoints	18 correct alerts out of 20	90%
4	Server Response Time	Local cloud deployment	Avg latency 220 ms	95%
5	Redis Live Lookup Speed	Continuous movement testing	4 ms average	99%
6	System Stability (8- hour Test)	Continuous city movement simulation	No crash were observed	98%

Accuracy Table

VI. CONCLUSION

This study examined the design and implementation of a Real-Time Ambulance Tracking System aimed at strengthening emergency medical response using modern mobile and web-based technologies. By integrating continuous real-time communication, fast in-memory data processing, and cross- platform mobile application development, the proposed system presents a reliable and scalable approach to addressing delays in emergency transportation.

Although certain practical challenges and limitations remain, the overall architecture demonstrates strong potential to improve coordination among emergency responders, traffic authorities, and healthcare facilities. By reducing response time and increasing operational transparency, the system can contribute significantly to public safety and better patient outcomes.

With further refinement, expanded testing, and large-scale implementation, such intelligent tracking systems could play a key role in the development of smart-city infrastructure and next-generation emergency management services.

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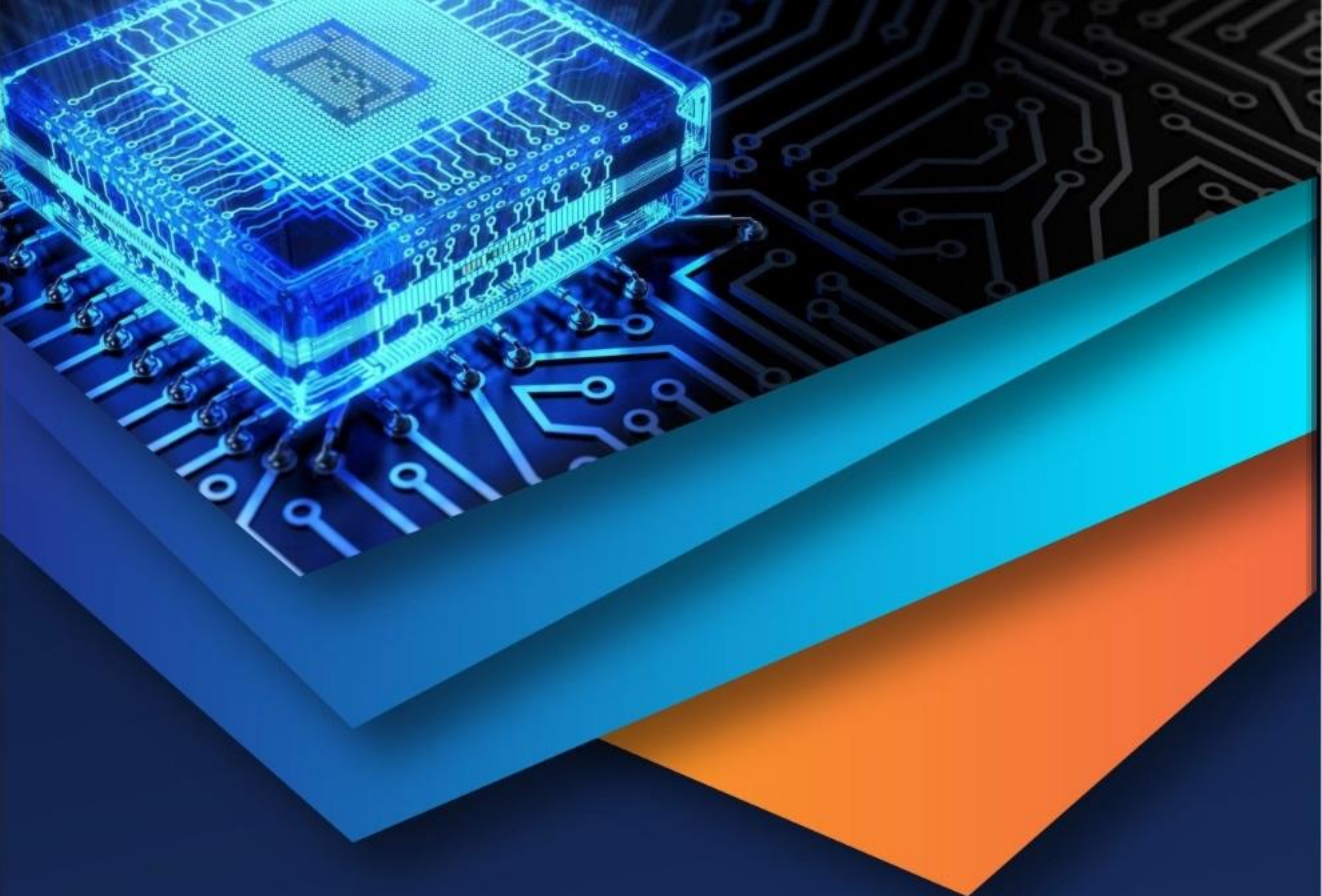

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